APPENDIX B – POTENTIAL INTERFERENCE TO AND FROM SATELLITE OPERATIONS

B.1 OPERATIONAL MISSION OVERVIEW

B.1.1 Satellite Operations Mission Overview

The United States (US) national security depends in significant measure on vital information provided by Department of Defense (DoD) and other critical, high priority US Government satellites. Satellite operations (SATOPS) allow for the control of more than 120 satellites and their payloads, transmission of mission data, and functions required to enable pre-launch, launch, and early orbit activities; on-orbit operations; anomaly resolution (emergency operations); and end-of-life management. The DoD performs Telemetry, Tracking, and Commanding (TT&C) SATOPS functions through ten Air Force Space Command (AFSPC) satellite control sites and through three Navy TT&C stations within the US and Possessions (US&P). The DoD also performs SATOPS functions outside of the US&P. This includes the Air Force Satellite Control Network (AFSCN) common user sites and dedicated Defense Support Program (DSP) and Global Positioning System (GPS) networks. TT&C is conducted via the space ground link subsystem (SGLS). Satellite control functions are absolutely critical to the operations of the spacecraft and payload. Without such control, satellites that provide for missile warning, navigation, military communications, weather, and intelligence, surveillance, and reconnaissance (ISR) would be jeopardized. The National Command Authority, Combatant Commanders, Services, and national level decision-makers would be severely impacted by a reduction or loss of the capability provided by these systems. In addition, other agencies, such as the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and commercial interests, would be adversely impacted as well as Allied forces.

Because of the vital information provided to the highest levels of the US Government by SATOPS systems, and the associated spacecraft, the potential impacts resulting from any degradation or loss of these systems must be carefully considered. The following factors were taken into account when evaluating potential impacts:

1. TT&C functions are critical to the control and maintenance of spacecraft. S-band offers physical advantages for TT&C operations, particularly in the areas of launch, early orbit, and anomaly resolution.

2. Most DoD on-orbit satellites operate on one discrete crystal-controlled frequency that cannot be changed after launch. Only a few satellites are capable of receiving commands on more than one frequency.
3. Satellite lifetimes often significantly exceed the design lives.
4. National and international satellite frequency registrations and coordination are completed over a period of years. Frequency changes to satellites scheduled for near-term launch may be unable to secure the protection that has been achieved via these regulatory actions.
5. It will be at least three years before a space-qualified crypto-enabled dual or multi-band satellite transponder is in production**.**
6. It will be 4-8 years before registration and regulatory actions for any additional SATOPS uplink frequency band are completed. There is no guarantee that all national and international frequency coordination will be successfully completed.

B.1.2 Mission Overview of Satellites Supported by SATOPS

The following paragraphs provide a mission overview for several satellite systems supported by SATOPS. This section is not intended to be a complete list of all satellite systems supported by SATOPS.

B.1.2.1 Global Positioning System

The Global Positioning System (GPS) provides navigational data and precise time transfer capability to military and civilian users all over the world. Uses of GPS include search and rescue, satellite radionavigation for aircraft, ship and terrestrial based navigation, communications, agriculture, and recreation. US Armed Forces utilize GPS for precision guided munitions, navigation for aerial, ground, sea-based, and underwater platforms, unmanned aerial and sea platforms, and Combat Survivor Evader Locator (CSEL) for Search and Rescue (SAR) operations. In addition to its navigation and timing missions, GPS provides essential nuclear detonation (NUDET) detection data integral to the United States Nuclear Detonation Detection System (USNDS) mission. USNDS utilizes GPS data to support Integrated Threat Warning and Attack Assessment, Nuclear Force Management, and Treaty Monitoring missions. The nominal GPS operational constellation consists of 24 satellites that orbit the earth once every 12 hours. GPS relies solely upon the 1755-1850 MHz frequency band for TT&C and mission upload capabilities.

The GPS constellation operates at Medium Earth Orbit (MEO). Currently, all Block II/IIA satellites and five of the twenty Block IIR satellites have been launched with the last IIR satellite to be launched in July 2006. With about 10 years average life of GPS satellites launch rates of two to four satellites per year are planned in order to sustain the GPS constellation. A total of 12 Block IIF satellites are being built. The launch of the first and the last IIF satellite are scheduled to be in January 2006 and January 2010 respectively. The first of the Block III satellites, that are being defined, is planned to be launched in January 2009.

The GPS ground segment consists of a master control station with 4-ground antennas and 6 monitor stations. The ground antennas currently use SGLS channel 6 with uplink frequency of 1783.74 ± 2 MHz to provide space vehicle (SV) commands, navigation message uploads, state-of-health operations and anomaly resolution.

The ground segment also uses AFSCN remote tracking stations to support satellite early orbit operations, anomaly resolution and as backups to the GPS ground antennas (GAs).

There is no planned retirement of the GPS constellation, but replacement satellites are scheduled for launch well past 2010. Some of these satellites have already been built and are ready for launch. Others are on the assembly line or in the planning stage.

B.1.2.2 Defense Satellite Communications System

The Defense Satellite Communications System (DSCS) is an integral component of the global Defense Information and Services Network (DISN). The DSCS, consisting of earth, space, and control segments and numerous subsystems, provides a reliable, high-capacity, quality communications capability in support of peacetime, contingency, and wartime operations. The DSCS is a geosynchronous satellite based system engineered and configured to provide vital command, control, and communications (C3) service including antijam connectivity for a number of high priority circuits to the US and Allied forces throughout the world. Specifically, the DSCS provides high availability communications services between the National Command Authorities (NCA) and the Combatant Commands; among the Combatant Commanders and their service component commands; between component commands and their organic combat forces; and, among early warning and sensor sites and command centers. DSCS relies solely upon the 1755-1850 MHz frequency band for TT&C capabilities.

B.1.2.3 Milstar

The Milstar satellite is the space element of a communications network comprised of a series of advanced satellites linked to mobile ground terminals providing assured command and control (C2) capabilities to US forces worldwide. The system provides undeniable connectivity, antijam communications and interoperability for multi-service coordination. These features are crucial to successful operations on the modern battlefield and are not available through existing military communications networks. New third-world threats and regional conflicts require rapid command and control capability providing multi-service interaction, fast deployment, and timely intelligence updates. Milstar provides the NCA and DoD users with worldwide survivable extremely high frequency communications. The system is flexible; on-board processing can reconfigure networks to suit evolving command and control requirements. Satellite crosslinks and onboard point-to-point routing offer direct connectivity between the NCA and deployed forces in the field. Advanced EHF is the follow-on to Milstar and will provide worldwide, secure, survivable satellite communications to US strategic and tactical forces and allied nations during all levels of conflict. It will sustain the military satellite communications architecture by providing connectivity across the spectrum of mission areas to include land, air, and naval warfare, special operations, strategic nuclear operations and defense, theater missile defense, space operations, and intelligence. Milstar conducts routine TT&C operations in mission bands but relies on S-band for launch, early orbit checkout and anomaly resolution.

B.1.2.4 Defense Support Program

The geosynchronous Defense Support Program (DSP) satellites help protect the US and its allies by detecting missile launches, space launches, and nuclear detonations. The DSP satellites use an infrared sensor to detect heat from missile and booster plumes against the Earth's background. Numerous improvement projects have enabled DSP to provide accurate, reliable data in the face of evolving missile threats. On-station sensor reliability has provided uninterrupted service well past their design lifetime. Recent technological improvements in sensor design include above-the-horizon capability for full hemispheric coverage and improved resolution. Increased on-board signal-processing capability improves clutter rejection. Enhanced reliability and survivability improvements were also incorporated. DSP relies solely upon the 1755-1850 MHz frequency band for TT&C. The Space-Based Infrared System (SBIRS) is the follow-on to DSP, but DSP operations will continue through 2020.

B.1.2.5 Midcourse Space Experiment

The Midcourse Space Experiment (MSX) satellite and its associated ground support infrastructure provide deep space surveillance. The MSX space-based system improves AFSPC mission of collecting data related to deep space orbits of military and commercial satellites without the limitations inherent in ground systems. These ground system limitations include location sensitivity, dependence on weather, and time of day requirements. MSX has helped to increase our revisit rates on militarily significant objects by 50 percent and has helped to reduce the list of lost satellites by 80 percent. It has enabled the development of standardized search techniques. MSX relies solely upon the 1755-1850 MHz frequency band for TT&C capabilities. There is currently no planned replacement for the MSX program when it flies out, circa 2006.

B.1.2.6 Defense Meteorological Satellite Program

The Defense Meteorological Satellite Program (DMSP) provides timely global and infrared cloud data and other meteorological, oceanographic and solar-geophysical data vital to DoD warfighting operations. The DMSP system consists of operational satellites in a near polar orbiting, sun synchronous orbit at an altitude of approximately 830 km. The current DMSP constellation consists of five spacecraft. On-board sensors record environmental data which is stored onboard and later relayed to strategic users through the use of several worldwide ground tracking stations. Military weather forecasters use this data to monitor and predict regional and global weather patterns, including the presence of severe thunderstorms, hurricanes, and typhoons. This information is used by meteorologists and plays a significant role in the planning of US military operations worldwide. DMSP also provides worldwide, real-time weather data to small tactical terminals in the battlefield.

The DMSP satellites also measure local charged particles and electromagnetic fields to assess the impact of the ionosphere on ballistic missile early warning radar systems and long-range communications. Additionally, this data is used to monitor global auroral activity and to predict the effects of the space environment on military satellite operations.

A convergence effort of military and civilian weather satellites has formed a single, converged national environmental satellite system, National Polar-orbiting Operating Satellite System (NPOESS), scheduled for launch in the 2007-2010 time frame. The command, control and communications for the DMSP have been combined with the control for Department of Commerce (DoC) satellites. In June 1998, DoC took over the primary responsibility for flying both satellites.

B.1.2.7 GEOSAT Follow-On

The Geostationary Satellite (GEOSAT) Follow-On (GFO) system provides global ocean surface height, significant wave height and wind speed measurements to Navy ship and shore (AN/SMQ-11) terminals in real time. Data is also stored on-board and later downlinked to the Naval Oceanographic Office for input to critical oceanographic and meteorological models. These models are used to plan naval operations, including ship routing, and to develop undersea environmental profiles that are critical to submarine operations. GFO relies solely upon the 1755-1850 MHz frequency band for telemetry and commanding functions.

B.1.2.8 Fleet Satellite Communications and Ultra High Frequency Follow-On

The Fleet Satellite Communications (FLTSAT) and Ultra High Frequency Follow-On (UFO) Satellite Communications systems provide a variety of communications capabilities to the DoD and other government agencies in support of a multitude of missions. These missions include supporting communications for the NCA, Joint Chiefs of Staff, and the Unified Combatant Commands.

The FLTSAT and UFO satellites support several different types of communications systems. These systems are Ultra High Frequency (UHF), Extremely High Frequency (EHF) and Global Broadcast Service (GBS). A brief technical description of these systems follows.

UHF Communications Systems support mobile users using small, inexpensive, low-power terminals, omnidirectional antennas, and operate in most weather conditions and under foliage. They typically function in a “bent-pipe” (frequency translation) mode, but one package, the Air Force Satellite Communications System (AFSATCOM), has a processing capability. The users of this system use Demand Assigned Multiple Access (DAMA) standards to maximize the use of the available channels. UHF communications on FLTSAT and UFO provide worldwide coverage (no polar coverage).

EHF Communications Systems support users requiring protected communications. EHF system characteristics include resistance to jamming and scintillation and provide Low Probability of Intercept, Detection, and Exploitation (LPI/LPD/LPE). These are processed systems using spread spectrum technology. The EHF system on UFO is capable of cross-banding to the UHF system on the satellite to support Fleet Broadcast. The EHF systems on FLTSAT and UFO provide worldwide coverage.

The GBS system supports mobile users with high bandwidth requirements for data. GBS is a broadcast system only, providing preplanned data products to a theater in a manner similar to direct broadcast television technology. There is a provision for receiving specific data products through the system but requires an alternate communications path back to the data providers. The characteristics of this system include high power transponders, small antennas for the receiver, multimedia data, and variable data rates. This system functions as a “bent-pipe.” GBS is presently available on three UFO satellites, providing partial worldwide coverage.

FLTSAT/UFO relies upon the 1755-1850 MHz frequency band for primary TT&C. FLTSAT and UFO will eventually be supplemented then replaced by the Mobile User Objective System (MUOS). First launch of a MUOS satellite is scheduled to occur in the 2007-2008 time frame.

B.1.2.9 NATO IV/Skynet 4

The North Atlantic Treaty Organization (NATO)/Skynet Systems provide communications to the British and NATO military forces. The NATO/Skynet networks consist of earth, space, and control segments and numerous subsystems and provide a reliable, high-capacity, quality communications capability in support of peacetime, contingency, and wartime operations. The US satellite command and control support is provided under international agreements. For US provided support, NATO/Skynet relies solely upon the 1755-1850 MHz frequency band for TT&C capabilities.

B.1.2.10 SMC/TE

The Air Force Space and Missile Systems Center Test and Evaluation (SMC/TE) directorate operates a series of research and development satellites and ground capabilities to test/demonstrate new technology and operational concepts. SMC/TE relies on SGLS for launch, on orbit control, and mission data for these satellites.

Several research and development (R&D) satellites using the SGLS uplink band (i.e., ARGOS and TSX-5) are currently in orbit but should reach end-of-life before 2003. However, additional R&D satellites are currently planned for launch in the 2003-2004 time frame. These include CORIOLIS, Cloudsat, and Communications/ Navigation Outage Forecast System (C/NOFS). The CORIOLIS mission, performing risk reduction for the NPOESS program, is scheduled to launch in mid-2002 with a minimum lifetime of three years. Cloudsat is a multi-year interagency mission, led by NASA, with DoD support that will profile cloud cover from space. Also, the C/NOFS is expected to launch in late 2003 with a minimum lifetime of three years. Both CORIOLIS and C/NOFS, which use the SGLS band, are expected to have operational utility to the warfighter following completion of their R&D objectives but should reach end-of-life before 2010.

B.1.2.11 Advanced EHF

The Advanced Extremely High Frequency (Advanced EHF) is the follow-on to Milstar and will provide worldwide, secure, survivable satellite communication to US strategic and tactical forces and International Partners during all levels of conflict. It will sustain the Military Satellite Communications architecture by providing connectivity across the spectrum of mission areas to include, land, air, and naval warfare; special operation; strategic nuclear operations; strategic defense; theater missile defense; and space operations and intelligence.

B.1.2.12 Wideband Gapfiller

The DSCS satellites provide responsive Super High Frequency (SHF) Wideband and Antijam communication supporting high data rate, long haul and strategic and tactical service worldwide. The objectives of the Wideband Gapfiller Satellite Program are to provide DoD wideband data services focused on tactical users and to augment existing DSCS and GBS (Global Broadcast System consisting of payloads on 3 UFO satellites) constellations.

B.2 SYSTEM DESCRIPTION

The DoD conducts SATOPS functions in the 1755-1850 MHz (uplink) and 2200-2290 MHz (downlink) bands to launch, checkout, and operate over 120 satellites flying in both geostationary and non-geostationary orbits. The Air Force, Navy, and Army, conduct satellite operations from several control nodes within the US&P and overseas. These control nodes communicate with satellites using a combination of global antenna networks. The DoD SATOPS uplink functions, which include the transmission of commanding and ranging signals, are performed in the 1755-1850 MHz band. Downlink telemetry data is passed via the 2200-2290 MHz band. The Air Force Satellite Control Network (AFSCN) and the Naval Satellite Operations Center (NAVSOC) serve as the primary DoD common-user satellite control networks. The AFSCN performs the bulk of the satellite operations through a worldwide network of US Air Force ground stations and control centers which provide telemetry, tracking, and commanding (TT&C) services to DoD and other satellites. The AFSCN consists of two control nodes, Schriever AFB, CO, and Onizuka Air Station (OAS) at Sunnyvale, CA, plus eight Automated Remote Tracking Stations (ARTS) dispersed both within and outside the US. In addition, the US Air Force has mobile (transportable) satellite ground stations that deploy worldwide and perform satellite control functions.

The GPS dedicated ground control network consists of Ground Antennas (GA) and Monitor Stations (MS) which are used to command, receive telemetry, monitor the navigation signals and provide navigation mission data uploads to the satellite constellation. The MS passively track the GPS satellite navigation signals. Signals collected by the MS are processed at the Master Control Station (MCS). The MCS uploads the GPS satellites with corrected navigation information via the GPS-dedicated GA and one modified AFSCN remote training station (RTS) using the SGLS band. In addition to performing the navigation mission data upload function, the GPS dedicated GAs are also the principal facilities used to conduct the GPS TT&C function. GPS does use the AFSCN for LEO&A operations, the same as most other DoD satellite systems.

NAVSOC remote TT&C facilities include Laguna Peak near Point Mugu; CA, Detachment ALFA at Prospect Harbor, Maine; and Detachment CHARLIE at Finegayan, Guam. The Navy also conducts TT&C operations from Blossom Point, MD, and Quantico, VA.

Figure B-1 depicts the locations of the fixed US&P DoD Satellite control stations. Table B-1 lists the DoD US&P Fixed satellite control nodes. Table B-2 lists the DoD US&P tracking and control antennas.

Table B-1. US&P DoD Fixed Satellite Control Nodes

Agency/Program	Location
Air Force Satellite Control Network	Schriever Air Force Base (AFB), CO Onizuka Air Force Station (AFS), CA
Defense Support Program	Buckley Air National Force Base (AFB), CO
Research, Development, Test and Evaluation Spacecraft	Kirtland AFB, NM
Navy Satellite Operations Centers	Naval Research Laboratory Blossom Point Field Site, MD Naval Satellite Operations Center at Pt. Mugu Naval Air Station, CA Naval Satellite Operations Center, Detachment Delta, Schriever AFB, CO
Global Positioning System (GPS Master Control Station (MCS)	Schriever AFB, CO Vandenberg AFB, CA

Table B-2. US&P DoD Command, Control and Tracking Antennas

Agency/Program	Location
Air Force Satellite Control Network	- Guam Tracking Station (GTS) – Andersen AFB, Guam - Colorado Tracking Station (CTS) – Schriever AFB, CO - Vandenberg Tracking Station (VTS) - Vandenberg AFB, CA - Hawaii Tracking Station (HTS) – Kaena Pt., Oahu, HI - New Hampshire Tracking Station (NHS) - New Boston Air Force Station (AFS) - Transportable antennas - Vehicle Checkout Facility – Cape Canaveral, FL - Camp Parks Communications Annex – Pleasanton, CA
Global Positioning System	- Ground Antenna – Cape Canaveral, FL - Ground Antenna – Kwajalein Island
Milstar (Milsatcom)	- Contractor Facility – Sunnyvale, CA
Defense Support Program	- Buckley AFB, CO
Navy Satellite Control Network	- Laguna Peak, CA - Prospect Harbor, ME - Finegayan, Guam - Blossom Point, MD

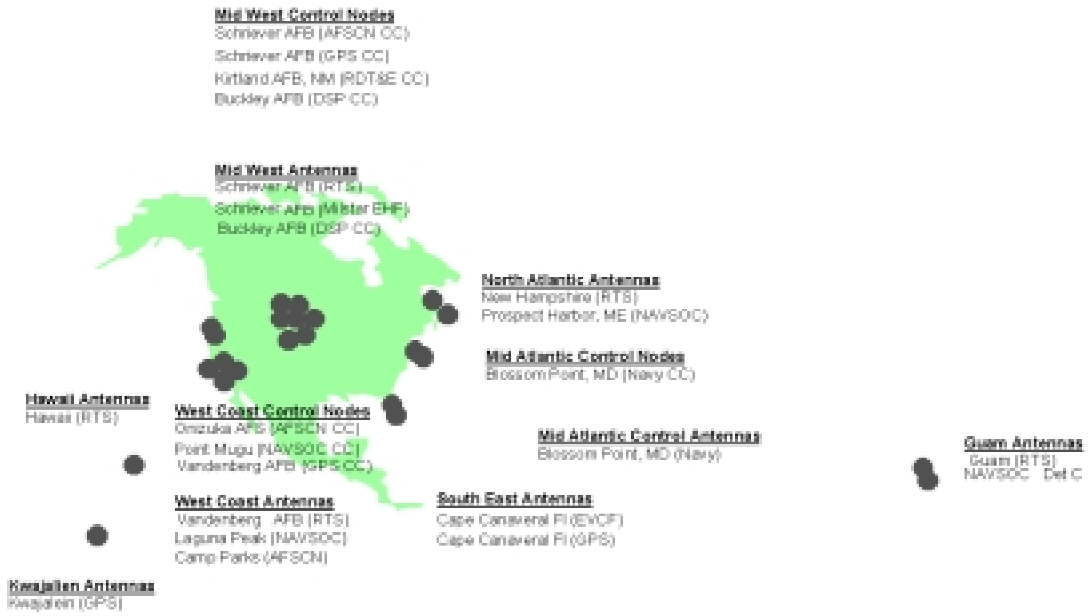

Figure B-1. Locations of the US&P DoD SATOPS Ground Stations

Table B-3 lists the 20 center frequencies for the standard AFSCN uplink frequency plan. It should be noted that most SATOPS uplinks conform to the 20-channel plan; however, select missions tune to channels in-between those reflected in the standard plan.

Table B-3. AFSCN SATOPS Uplink Frequency Plan

S-band Channel	Uplink Frequency Transmission (MHz)	S-band Channel	Uplink Frequency Transmission (MHz)
1	1763.720703	11	1803.759766
2	1767.724609	12	1807.763672
3	1771.728515	13	1811.767578
4	1775.732422	14	1815.771484
5	1779.736328	15	1819.775391
6	1783.740234	16	1823.779297
7	1787.744141	17	1827.783203
8	1791.748047	18	1831.787109
9	1795.751953	19	1835.791016
10	1799.755859	20	1839.794922

B.3 COST ISSUES

B.3.1 Satellites

DoD recently established the long-term goal of transitioning (no earlier than 2020 to 2025) the uplink frequency band for Launch, Early Orbit and Anomaly resolution (LEO&A) from 1761-1842 MHz to 2025-2110 MHz. In support of this goal, the DoD has included the requirement in two current and planned DoD satellite contracts for the satellites to carry a USB transponder. The costs to do this were not included in the cost estimates provided in this report. A final decision on the transition will be made after more detailed study and a determination if this band could provide the assured access required for DoD satellite operations.

GPS satellites use 1761-1842 MHz to both perform LEO&A and to upload their mission data. For the purposes of this report, GPS III, the next generation GPS space and controls segment will include a USB capability for LEO&A operations and a 5000-5030 MHz (5 GHz) capability to support upload of navigation mission data and “in band” commanding. All the costs both to the space vehicles and to the GPS ground stations to relocate to 5 GHz are attributable to IMT-2000 and are included here. The delta cost to change from SGLS to USB for the GPS III satellite is negligible and no costs for this are included in the report. No modifications to the Block II/IIA/IIR/IIF satellites with respect to TT&C capabilities are planned, so costs are not included for these. Those satellites will use SGLS until they fly out.

Any migration of DoD systems will not be feasible until at least 2010 or beyond. Hence, Table B-4 makes no cost distinction by introduction date. The costs of the segmentation and options differ by which SGLS channels are lost to DoD and which are maintained. Of course, total loss of the band is not possible for space systems until at least 2017 or beyond. Depending on the timing of the decision concerning the introduction of IMT-2000 into this frequency band, costs for the Wideband Gapfiller and Advanced EHF systems could vary greatly. The costs presented in Table B-4 for these programs reflect a decision date by July 2001. Should the decision go beyond that date, these two programs may incur substantial cost increases, which are not reflected in Table B-4.

Table B-4. Satellite Reimbursement Cost for Vacating the Band (TY$M)

	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
Milstar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wideband Gapfiller Satellite (WGS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DSCS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DMSP	0.0	6.3	14.9	7.7	9.2	2.5	1.4	42.0
Advanced EHF	0.0	0.0	0.0	0.8	0.0	1.7	1.7	4.2
SBIRS High	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SBIRS Low	6.0	8.8	5.2	1.4	0.0	0.0	0.0	21.4
GPS	0.9	0.9	2.9	23.8	7.1	16.7	118.2	170.5
MUOS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UFO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FLTSAT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**6.9**	**16.0**	**23.0**	**33.7**	**16.3**	**20.9**	**121.3**	**238.1**

B.3.2 Satellite Command and Control Ground Stations

The DoD currently has numerous programs which operate ground stations that broadcast over SGLS. The Air Force Satellite Control Network (AFSCN) is the primary system and supports TT&C activities for virtually all DoD systems as well as other agencies, civil users, and Allied nations. The US Navy Satellite Control Network controls various Navy satellites. GPS operates several of their own ground stations because, unlike other DoD satellite programs, GPS also uses SGLS to upload their mission data. DSP, and the follow-on program SBIRS High, have a critical early warning function and maintain their own SGLS ground system for TT&C to ensure their operations are not interrupted.

The proposed AFSCN/IMT-2000 mitigation options (band segmentation) require the local IMT-2000 service provider to implement a dynamic frequency allocation system. This system could sense if the local AFSCN site was emitting and, on what channel, and could then dynamically allocate its users to the unused portion of the band. Also, AFSCN could implement channel filters on its antennas to reduce out-of-channel emissions and finally, if necessary, could relocate the ground stations to remote sites. It is not possible to implement all of these ground station changes prior to 2003, or even 2006, but they could be completed by 2010. AFSCN costs for band sharing assume coordination zones and are for channel filters only. AFSCN costs for band segmentation/vacating the band include channel filters and ground station relocation.

The strategy of ground site relocation of some US&P sites would be a consideration with band segmentation; however, it is not clear that it will be possible to identify sites for which all of the necessary paperwork can be obtained by 2010. This is because it will be necessary to obtain BRAC permission to move, obtain regulatory and/or legislative protection of SATOPS use at the new site, and to obtain environmental permission for site development. Cost impacts for those issues have not been provided.

Tables B-5 and B-6 show the costs for both filtering and relocation of the ground stations, respectively.

Table B-5. Satellite Ground Segment Filtering Costs (TY$M)

	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
Ground Segment Filtering	**11.3**	**11.5**	**11.8**	**12.0**	**12.2**	**12.5**	**38.9**	**110**

Table B-6. Satellite Ground Segment Relocation Costs (TY$M)

	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
AFSCN	33.6	34.1	41.8	42.5	43.3	44.1	245.5	485.0
GPS	0.0	0.0	13.3	18.5	7.4	366.6	540.7	946.5
SBIRS High	49.3	68.6	38.8	11.4	2.5	2.5	50.7	223.8
GFO / NAVSOC	20.5	1.2	1.2	1.2	1.2	1.2	18.0	44.5
IMT-2000 Reimbursement	**103.4**	**103.9**	**95.1**	**73.6**	**54.4**	**414.4**	**854.9**	**1,699.8**

As discussed in the satellite section, GPS Block III plans to use USB for LEO&A and 5 GHz for navigation mission data uploads and “in band” commanding. SGLS will continue to be used for all TT&C operations and mission data uploads for the Block II/IIA/IIR/IIF satellites. Under the band sharing option there is no known cost impact. Similarly, since GPS operates on SGLS channel 6, options 2A and 3A (band segmentation) would allow DoD to retain channel 6 so there would be no cost impact to GPS. However, under band segmentation option 2B or 3B or if the entire band is lost, option 4, GPS would be required to move its mission data link to the 5 GHz band, which would entail substantial effort and cost. This move would be done in concert with the GPS III program and so would not differ significantly depending upon the introduction date of IMT-2000.

B.4 OPTION 1 – FULL BAND SHARING

B.4.1 Operational Impact

DoD must retain primary user status for SGLS SATOPS functions throughout the band for all on-orbit satellites until their end-of-life. Legacy satellite systems are expected to require SGLS support through 2030. Denying SATOPS the spectrum required to support on-orbit assets will result in a partial or complete loss of TT&C capability. This applies to any of the sharing, segmentation, or band vacating schemes. Denied spectrum access will result in varying degrees of impact to the spacecraft including orbit-positioning errors, loss of payload control leading to eventual malfunctions and mission failure, and ultimately, complete loss of the satellite. Mission capabilities for missile warning, navigation, military communications, weather, and intelligence, surveillance and reconnaissance would be severely impacted until such time as a combined satellite and ground station system in an alternate frequency band could be built and put into operational service. This would include impacts to military communications at all levels of conflict, Navy communications to the fleet, and national intelligence data, and military communications for our NATO Allies under international support agreements.

Assuming that spectrum access is assured, the operational impact to SATOPS capabilities is dependent upon two factors:

1. the impact to satellite uplink closure reliability as a result of the IMT-2000 emissions, and
2. the restrictions placed upon ground based uplink capability as a result of the mitigation techniques required to preclude EMI to IMT-2000 receivers.

Operational impact to TT&C uplinks from IMT-2000 emissions is expected in the time period 2006 and beyond when IMT-2000 system build-out has exceeded 50 % of ITU estimates for full capacity. In 2003, it is not expected that IMT-2000 build-out will be sufficient to impact SATOPS uplink operations. These results are based upon near-worst case but realistic uplink parameters. It should be noted that if uplinks were conducted from worst-case disadvantaged (size, power, restricted viewing, etc.) terminals using antennas smaller than 33 feet or lower transmitter powers, there is a potential for impact to link closure reliability in 2003. The degree of operational impact will vary as a function of the degree to which link closure is affected. It is expected that impact would occur for only a small set of systems and operating conditions, although at critical junctures such as launch or anomaly resolution, such impact would be critical.

In the 2006 and beyond timeframe, IMT-2000 emissions are expected to impact uplink closure reliability at all orbit heights with the greatest affect occurring at LEO (approximately 850 km) and medium earth orbit (MEO), approximately 20,000 km, orbit heights. Systems most impacted by this include GPS, DMSP, and certain ISR systems. Should link closure be degraded to the point where commanding cannot be performed, the impacts enumerated previous for denied spectrum access would occur. Note that there is no expected impact to MSX satellite in 2006 given that the satellite will have reached end of its predicted life.

Operational impacts on the SATOPS ground assets are generally limited to issues associated with the IMT-2000 RFI mitigation techniques. The primary mitigation technique exclusive to the IMT-2000 community is the establishment of coordination zones, areas surrounding SATOPS uplink sites within which IMT-2000 operations may be affected. The location and approximate size of these areas are illustrated in the technical assessment section of the report. Assuming SATOPS functions continue unencumbered at all current uplink locations, and that IMT-2000 systems accept the potential limitations within these coordination zones, no operational impact to DoD SATOPS ground assets is anticipated

Other IMT-2000 RFI mitigation techniques such antenna elevation angle restrictions and SATOPS uplink power restrictions offer limited benefit and in general prove operationally unacceptable due to impacts to satellite contact time and link margin.

Dynamic frequency reallocation, a technique where the IMT-2000 systems change frequencies in real time to take advantage of the SATOPS changing frequency requirements, may have varying impact on DoD ground-based SATOPS operations depending upon the specific implementation schemes. Techniques to implement this RFI mitigation scheme need to be explored in detail with the IMT-2000 community, however the impact to DoD operations may prove to be manageable.

In 2006 and beyond, the DoD will be continuing to work toward satellite control site upgrades; however, it will be necessary to continue operating on SGLS frequencies until all on-orbit satellites requiring SGLS commanding have reached their end of life.

By the 2010 time frame, two significant changes will occur:

1. most affected SGLS sites could be modified for SATOPS in an additional uplink band thus allowing the flexibility of alternate frequency use for more recent launches, (provided that no satellite or ground system program experienced delays) and
2. the IMT-2000 system build-out may have achieved levels that will quite likely result in the inability to reliably close the TT&C command uplink.

Regardless of the alternate frequency capabilities at the ground sites available in 2010, SGLS uplinks will still be required to control many on-orbit satellites. Legacy satellite systems are expected to require SGLS support through 2020-2025. By 2010 the likelihood for SATOPS uplink receiver degradation will increase as IMT-2000 nears full forecasted build out. Under these conditions, assured spectrum access alone will not preclude the impact to spacecraft/payload commanding and the associated satellite mission due to increased background power spectral density.

B.4.2 Technical Assessment

B.4.2.1 Interference from Ground Elements to IMT-2000

B.4.2.1.1 Assessment Approach

In order to assess the potential for interference to a geographically dispersed network of IMT-2000 fixed and mobile receivers, an automated model was used to generate received signal overlays as a function of transmitter and receiver parameters and terrain-dependent path loss. The results are displayed as a raster or grid of color-coded signal levels overlaid on a map. The basis for the terrain-dependent path loss calculations within the model is the Terrain-Dependent Path Loss Model (TIREM). This model considers obstructions due to terrain but does not consider additional losses due to man-made structures or foliage.

In recognition of the significant variations in SATOPS transmitter uplink and IMT-2000 receiver configurations, a parametric analysis was performed. For SATOPS uplink functions, minimum antenna elevation angles of 3, 5, and 10 degrees were selected for comparative analysis purposes only. However, 10 degrees is not acceptable from an operational perspective. Additional higher minimum elevation angles were not considered because the minimal benefit in sidelobe reduction was offset by the significant impact to operations. Based on current antenna configurations, significant sidelobe reduction is not realized until well outside of the mainbeam. These angles would be prohibitively large for typical SATOPS functions, particularly for those conducted on satellites flying in non-geostationary orbits.

For the IMT-2000 receivers, separate overlays were generated for the base stations and mobiles/portables in recognition of the differences in receiver antenna height, antenna gain, and interference threshold.

B.4.2.1.2 Analysis

The following equation was used to define the regions surrounding the SATOPS uplink sites where impact to IMT-2000 receivers may occur.

$$I = P_t + G_t + G_r - L_p - L_s - FDR$$

where

I	=	Assumed interfering signal level, at the IMT-2000 receiver input, in dBm
P_t	=	SATOPS transmitter power, in dBm
G_t	=	SATOPS transmitter antenna gain at the horizon, in dBi

G_r = IMT-2000 receiver antenna gain in the direction of the SATOPS transmitter, in dBi
L_p = Terrain-dependent path loss, in dB
L_s = IMT-2000 receiver system loss, in dB
FDR = Frequency-dependent rejection, in dB.

Given that the interference estimate varies as a function of the SATOPS transmitter/antenna configuration and IMT-2000 receiver susceptibility thresholds, a parametric assessment was performed for several representative SATOPS uplink sites. Table B-7 lists the SATOPS uplink sites included within this assessment. These sites were selected to represent a variety of functions, orbit types, and local terrain features over a geographically dispersed region. It is expected that the results achieved for these sites are generally representative of the potential for EMI at all SATOPS uplink sites.

Table B-7. SATOPS Uplink Sites Included in this Assessment

Terminal Name	Abbreviation	Alt Name	Location	Latitude/ Longitude	Number of Terminals	Terminal Size (feet)
Colorado Tracking Station	CTS	Pike	Colorado Springs, CO	38 48 21 N 104 31 43 W	1	33
New Hampshire Tracking Station	NHS	Boss	Manchester, NH	42 56 52 N 071 37 37 W	3	60 46 33
Onizuka Air Station	OAS	Sun	Sunnyvale, CA	37 24 25 N 122 0134 W	1	51
Eastern Vehicle Check-out Facility	EVCF	EVCF	Cape Canaveral, FL	28 27 29 N 080 34 32 W	1	23
Hawaii Tracking Station	HTS	Hula	Kaena Point, Oahu, HI	21 33 48N 158 14 54W	2	60 46
Guam Tracking Station	GTS	Guam	Anderson AFB Guam	13 36 54N 144 52 00E	2	60 46

Transmitter maximum powers in Table B-8 represent the maximum transmitter capability of the high power amplifier connected to the terminal. A minimum power of 100 Watts was selected to represent best-case EMI uplink powers under the assumption that link closure can be achieved at this level. In many instances, a transmit power of 250 Watts, 500 Watts, or even 1 kW is required for link closure to a healthy, stable, on orbit satellite. However, results from the overlays will indicate that several dB of variation in the transmit power assumptions will not change the conclusions that can be drawn from the data.

Antenna off-axis gains were determined from computer generated antenna patterns. Antenna off-axis gain at the horizon was calculated assuming 3, 5, and 10-degree minimum elevation angles. As discussed in the approach, these levels are considered to be within the range of acceptable values for analysis purposes. From an operations concept perspective, 3 degrees is acceptable, 5 degrees is acceptable for select missions, and 10 degrees is operationally unacceptable. Figures B-2 through B-5 are computer generated antenna patterns for the 60, 46, 33, and 23-foot antenna diameters. These figures were used to calculate the off-axis antenna gains at the 3, 5, and 10-degree minimum elevation angles."

Table B-8. SATOPS Model Inputs

Terminal	TX Powers (Watts)	Antenna Diameter (ft)	Antenna off-axis gain (dBi)			Effective Isotropic Radiated Power (EIRP) (dBm)		
			3º	5º	10º	3º	5º	10º
CTS	2.25K max/100 min	33	8	5	3	72/58	69/55	67/53
NHS	10K max/100 min 2.5K max/100 min 1K max/100 min	60 (A) 46 (B) 33 (DLT)	24 18 8	17 5 5	12 3 3	91/71 82/68 68/58	87/67 69/55 65/55	82/62 67/53 63/53
OAS	2K max/100 min	51 (DLT)	18	5	3	81/68	68/55	66/53
EVCF	2.25K max/100 min	23	23	16	12	87/73	80/66	76/62
HTS*	2K/500/100	46	18	No Analysis	3	81/75/68	No Analysis	66/60/53
Guam*	7Kmax/100 min	46**	18		3	90		59

(A), (B), and (DLT – Data Link Terminal) are designators used to differentiate between unique site locations.
*Only a limited set of conditions were considered for the HTS and GTS sites.
**The actual configuration for the Guam site is a 7K maximum power, with a 60-foot antenna. The 46-foot diameter was used for model inputs.

Table B-9 lists the IMT-2000 data used to generate the received signal overlays. This data has been coordinated with the FCC and is consistent with IMT-2000 system specifications used to assess the other types of DoD systems in the band. Receiver interference thresholds are grouped into 10-dB bins from the most sensitive threshold provided (-121 dBm) up to greater than -71 dBm. This range of thresholds more than encompasses the region of acceptable interference values.

Table B-9. IMT-2000 Receiver Data

IMT-2000 Platform	Receiver Interference Thresholds Plotted (dBm)	Receiver Antenna Height (Meters)	Receiver Antenna Gain (dBi)
Fixed Base Stations	<-121 -111 to –121 -101 to –111 -91 to –101 -81 to –91 -71 to –81 > -71	40	17
Mobiles and Portables	<-105 -95 to –105 -85 to –95 -75 to –85 >-75	1.5	0

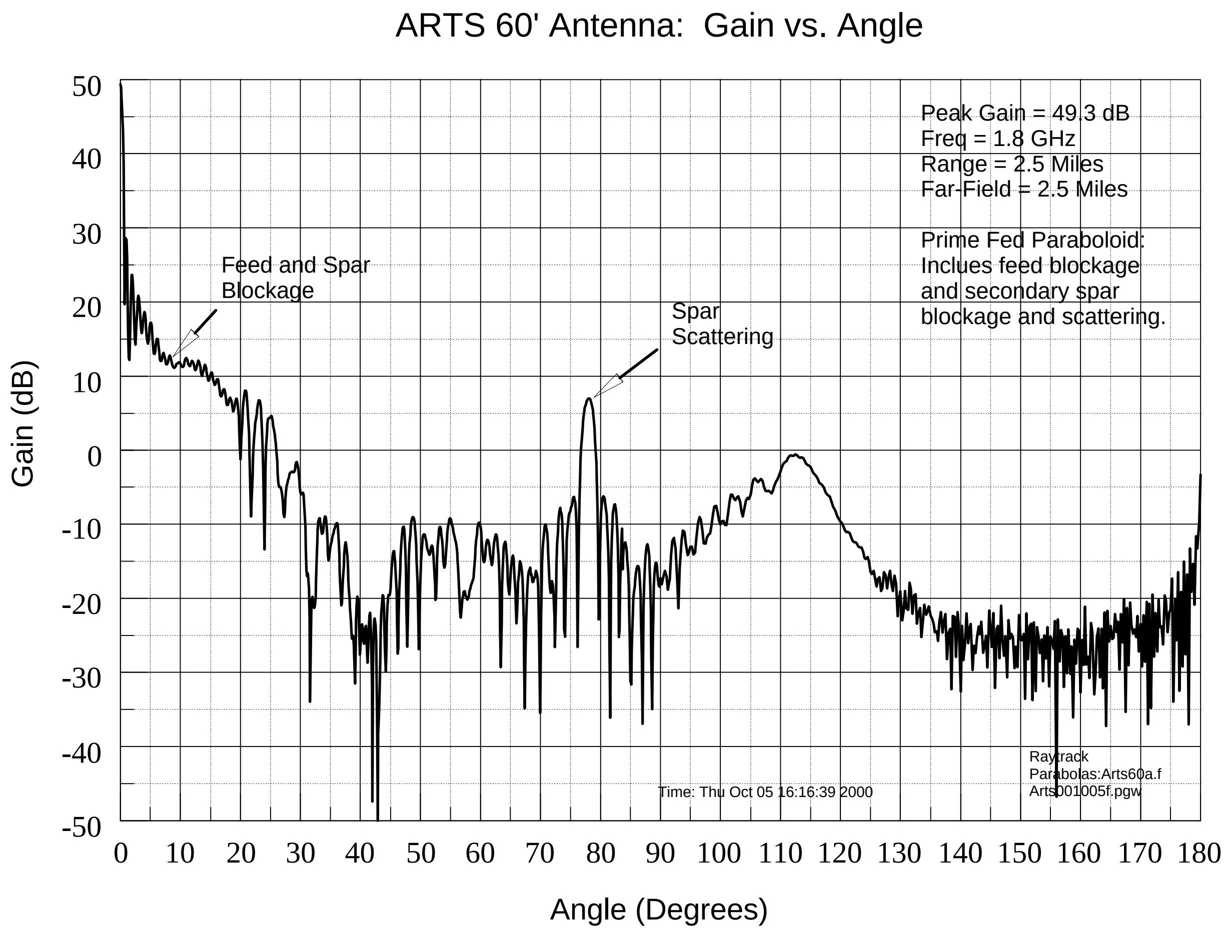

Figure B-2. Computer Generated Antenna Pattern for the Automated Remote Tracking Station (ARTS) 60-foot Antenna Diameters (Antenna Gain Values are in dBi)

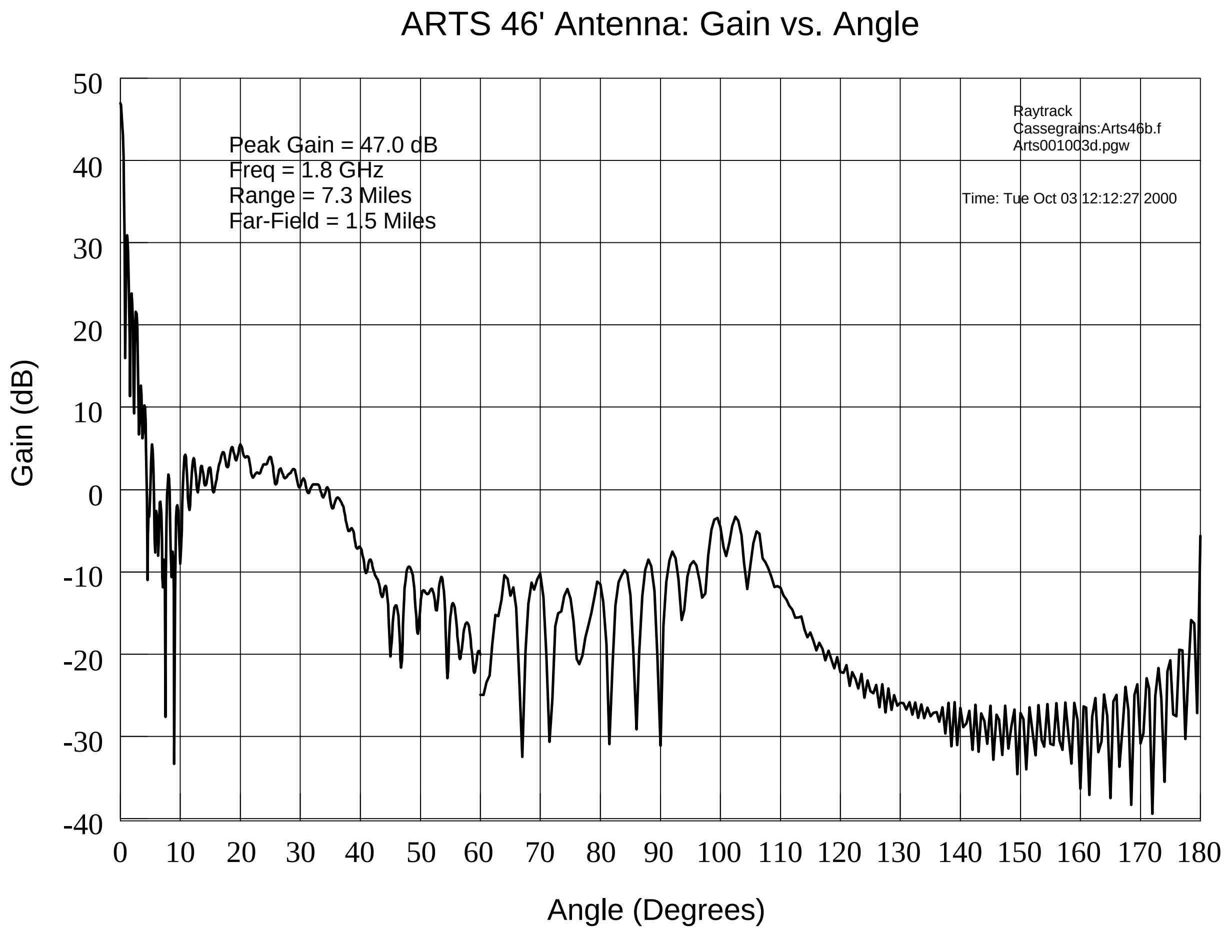

Figure B-3. Computer Generated Antenna Pattern for the 46-foot Antenna Diameters (Antenna Gain Values are in dBi)

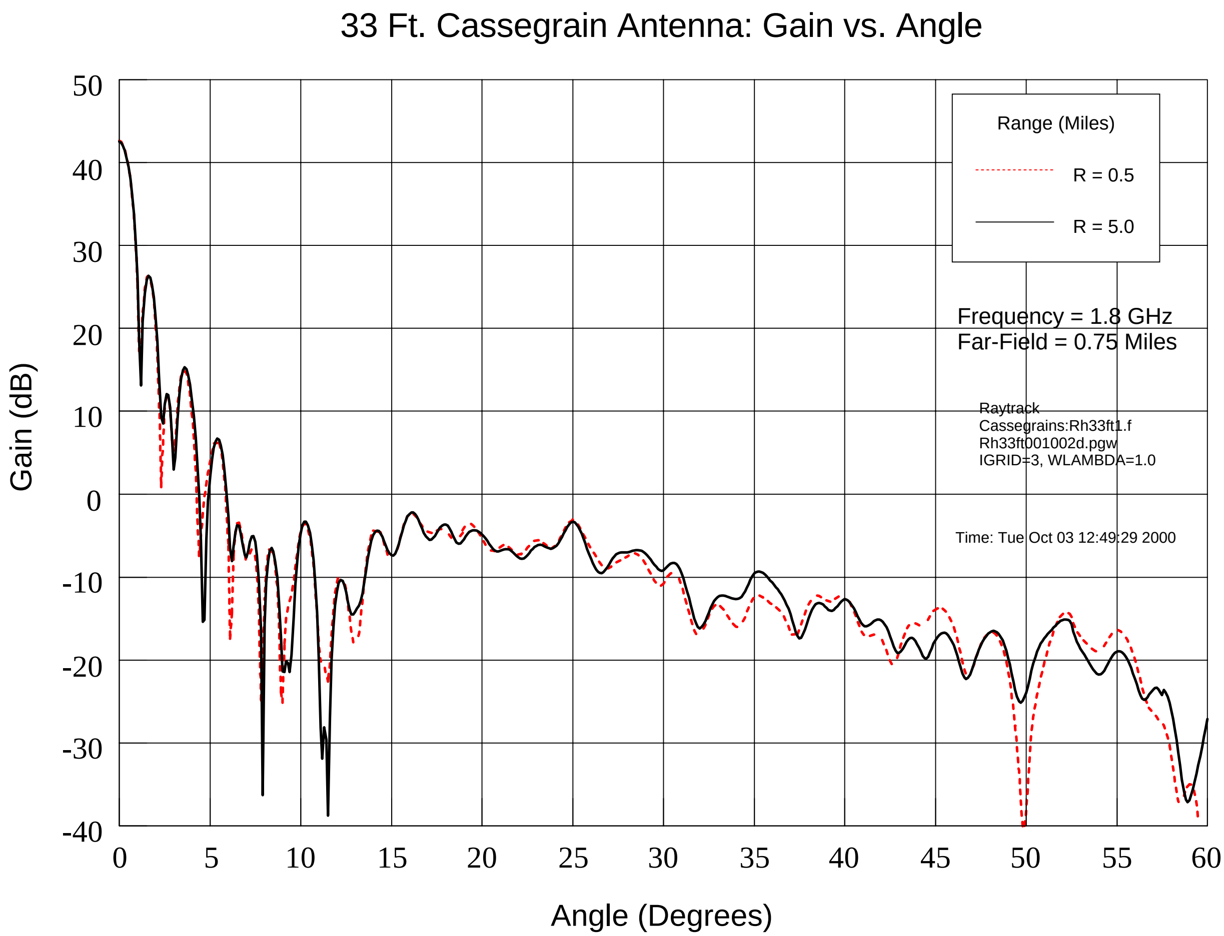

Figure B-4. Computer Generated Antenna Patterns for the 33-Foot Antenna Diameters (Antenna Gain Values are in dBi)

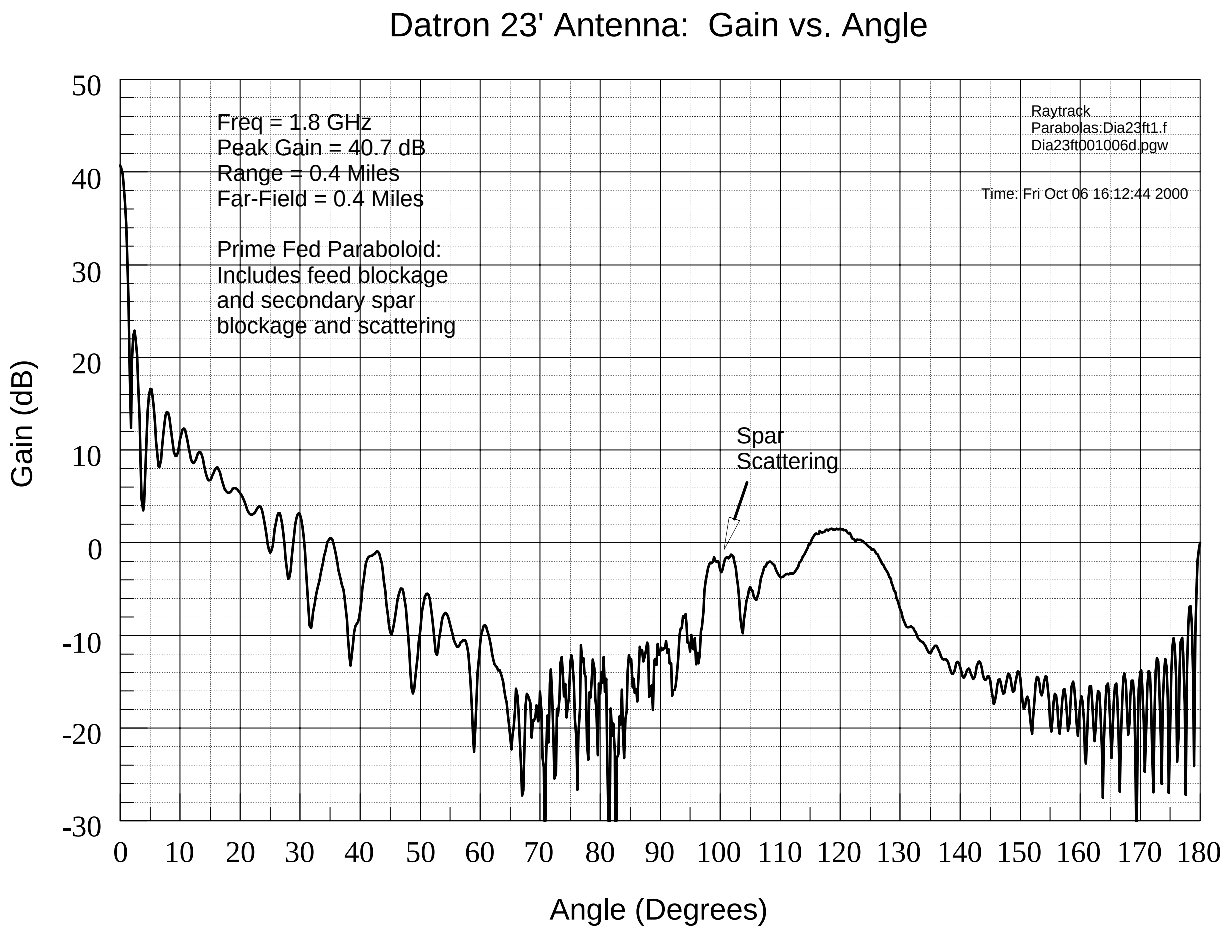

Figure B-5. Computer Generated Antenna Patterns for the 23-Foot Antenna Diameters (Antenna Gain Values are in dBi)

B.4.2.1.3 Results

Results of the signal level predictions for the six sites analyzed, CTS, NHS, OAS, EVCF, Hawaii, and Guam, are contained in Attachment 1. Three-dimensional topographic displays of the regions surrounding the sites are included to illustrate the relationship between terrain and predicted received signal level. The signal level plots do not reflect any additional attenuation due to blockage from man-made structures. In dense urban areas man-made structures may provide an additional 10-20 dB of attenuation which could reduce the interference to mobile stations with low antenna heights. Several plots are included within this section for discussion. A legend in the upper right corner of the overlays defines the IMT-2000 received threshold plotted. It should be noted that the –121 dBm threshold, which is depicted as white in the legend, is portrayed as yellow on the overlays. Below the legend are all of the input parameters used to generate the overlay.

Figure B-6 is an overlay for the worst-case conditions at NHS: maximum transmitter power (10 kW), and minimum elevation angle (3 degrees). Worst case overlay conditions apply to the IMT-2000 base stations vice the mobiles due to the increased antenna height (40 meters) and higher antenna gain (17 dBi) associated with the fixed sites. As shown in the figure, no region within the 70 X 70 km area shown meets the -121 dBm threshold. In fact, virtually all of the area depicted in the overlay experiences levels in excess of -71 dBm, well in excess of what might be considered a reasonable threshold level for the IMT-2000 receivers. Figure B-7 depicts the coverage for the same site under best-case transmitter conditions, 100 Watt transmitter power, and a 10-degree minimum elevation angle. While there is a noted reduction in the region exposed to levels in excess of -71 dBm, there is still no area that meets or even approaches the -121 dBm threshold specified. Figure B-8 depicts the best case overall (from an interference perspective) in that it depicts signal levels to a mobile receiver (reduced antenna height and antenna gain) at the lowest SATOPS transmit power and highest antenna elevation angle. Under these conditions, significant improvement is noted from the previous overlays; however, there are still significant portions that extend out 70 km and beyond from the site that exceed the -105 dBm threshold.

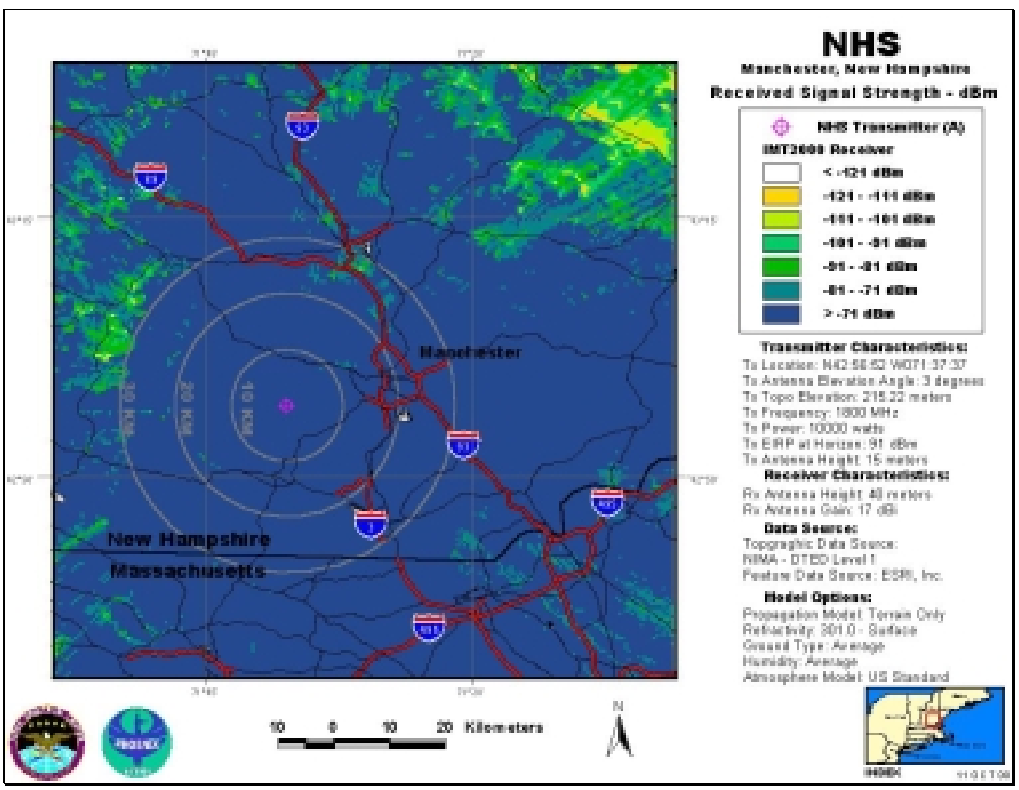

Figure B-6. NHS-A, Antenna Elevation Angle: 3°, Transmitter Power: 10,000 W, IMT-2000 Base Station

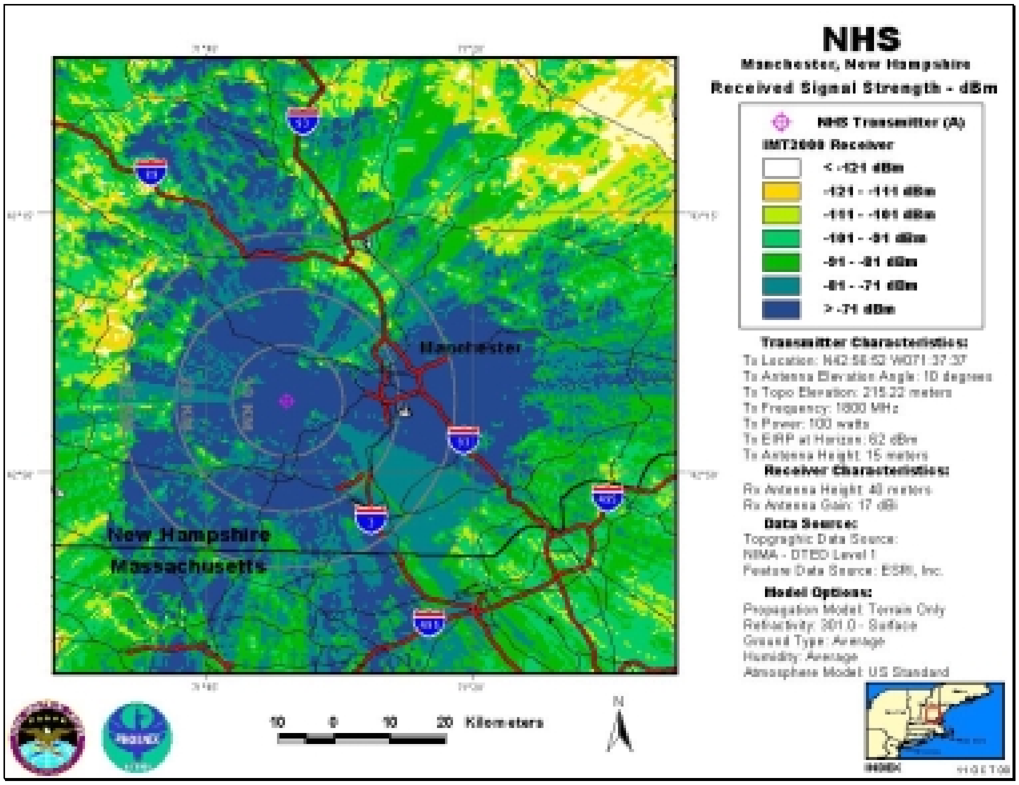

Figure B-7. NHS-A, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Base Station

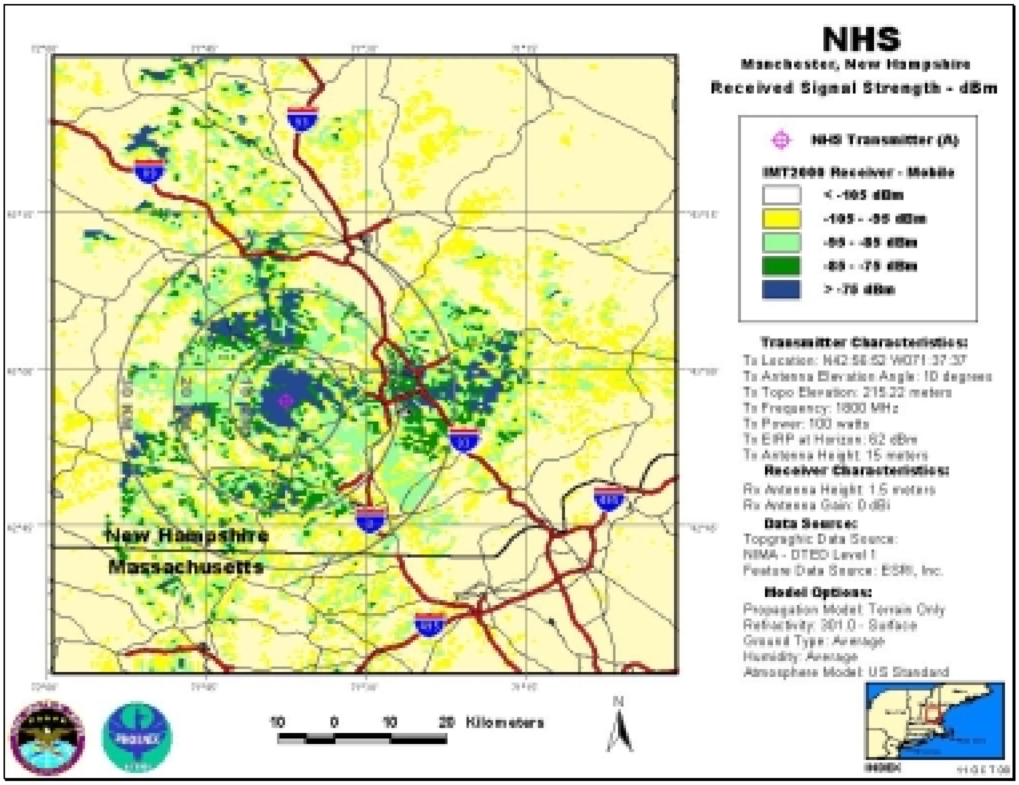

Figure B-8. NHS-A, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station

A review of the other sites analyzed produces similar results. Figure B-9 represents worst-case SATOPS uplink conditions (maximum power, low elevation angle) for the OAS site. Like the NHS overlays, signals in excess of -71 dBm extend well beyond 70 km from the uplink terminal. Under these conditions, electromagnetic interference (EMI) from OAS extends well beyond the highly populated and highly desirable market regions of Oakland and San Francisco. Even under best case conditions (10 degrees and 100 Watts), Figure B-10 illustrates that the areas in excess of -121 dBm extend well over 75 km from the site. Figure B-11 depicts impact to IMT-2000 mobile users under best-case SATOPS uplink conditions. Like the NHS case, this represents the smallest potentially affected area. However, the region impacted still encompasses highly desirable regions from an IMT-2000 market perspective.

One exception to the overlay results applies to the IMT-2000 mobiles surrounding the Hawaii Tracking Station. At this location, terrain plays a significant role in attenuating the SATOPS undesired signal levels in the populated areas of Oahu. Hence the potentially affected area is fairly limited. Figure B-12 illustrates that the impact to IMT-2000 mobiles on Oahu with a SATOPS transmitter power of 500 Watts and a 10-degree antenna elevation angle. Most portions of the Island meet the desired interference threshold of -105 dBm.

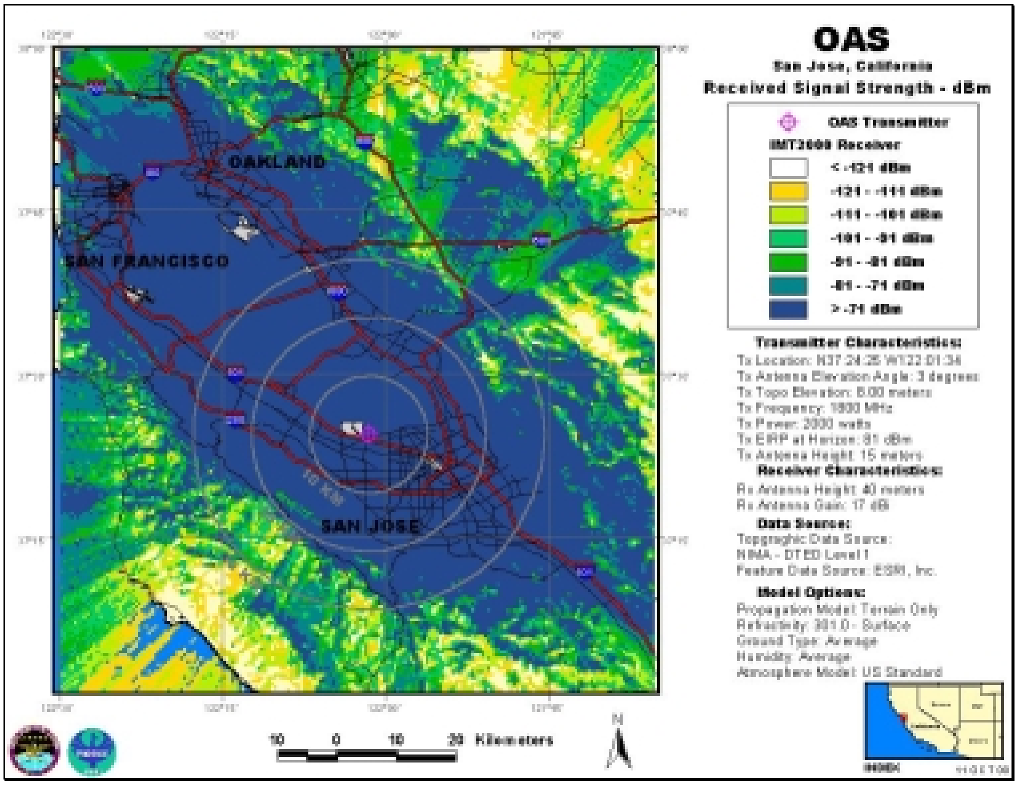

Figure B-9. OAS, Antenna Elevation Angle: 3°, Transmitter Power: 2,000 W, IMT-2000 Base Station

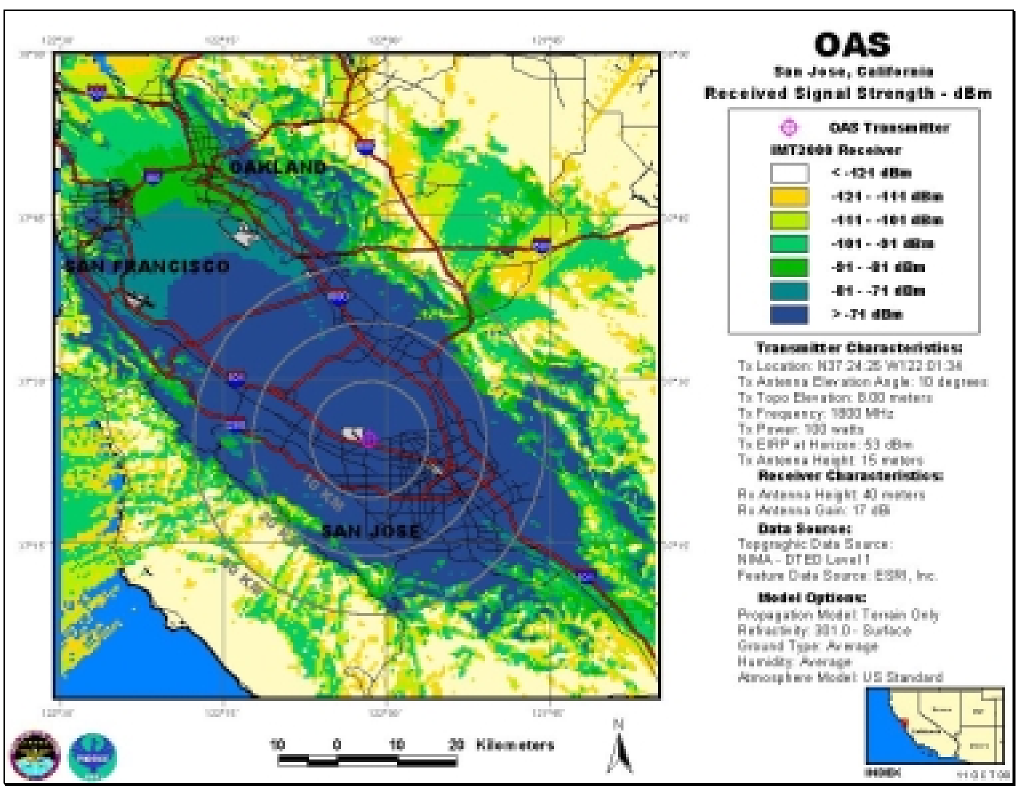

Figure B-10. OAS, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Base Station

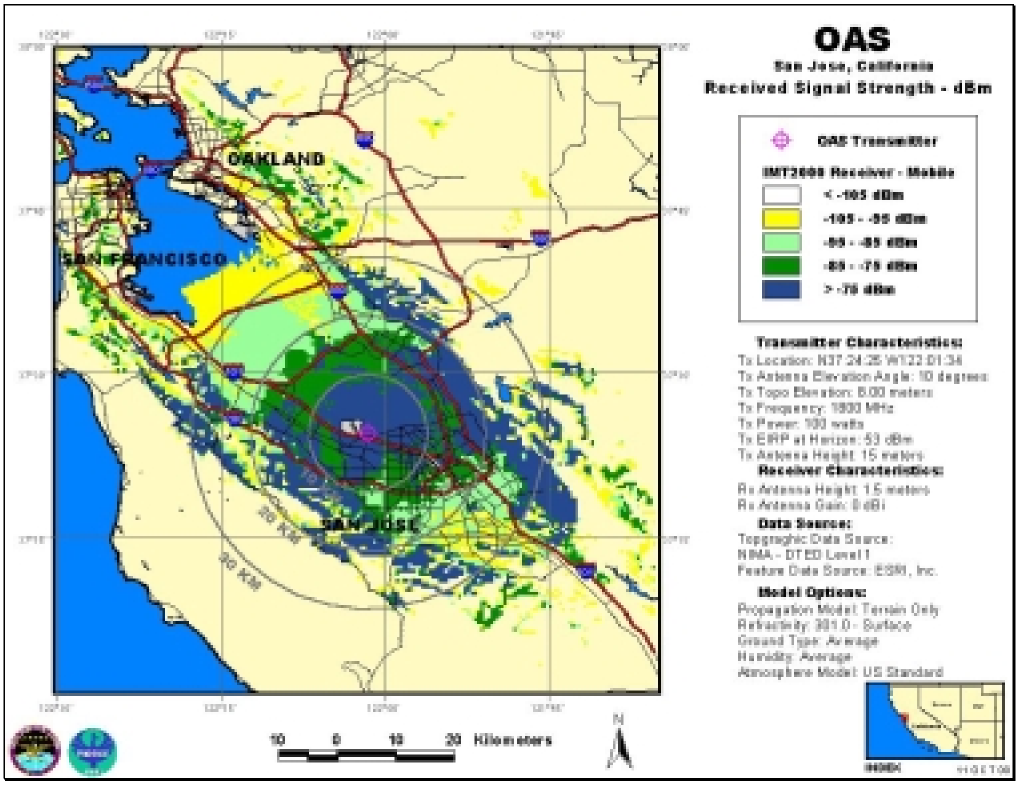

Figure B-11. OAS, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station

It should be noted that the assessment assumes 360-degree coverage for the HTS SATOPS antenna. While for many sites this is true (including NHS), there are some sites that do concentrate activities within specific azimuth ranges, thereby lessening the effects to IMT-2000 receivers at large off-axis angles relative to the SATOPS mainbeam. It is also worthy of note that SATOPS uplink terminals only transmit on one channel at a time thereby lessening the impact to IMT-2000 users on nearby operating frequencies. This fact, coupled with the specific antenna azimuth operations, allows for the possibility of sharing on a time/frequency basis.

To illustrate the variation in impact as a function of azimuth for a fixed pointing antenna, four additional plots were generated. Figures B-13 and B-14 illustrate the base and mobile received signal levels for a 2000-Watt SATOPS uplink power and a 3-degree elevation angle. Figures B-15 and B-16 illustrate the base and mobile received signals for a 10,000-Watt SATOPS uplink power and a 3-degree elevation angle, plus an additional 50 dB of signal attenuation. In all four instances the antenna was fixed in azimuth at 33 degrees.

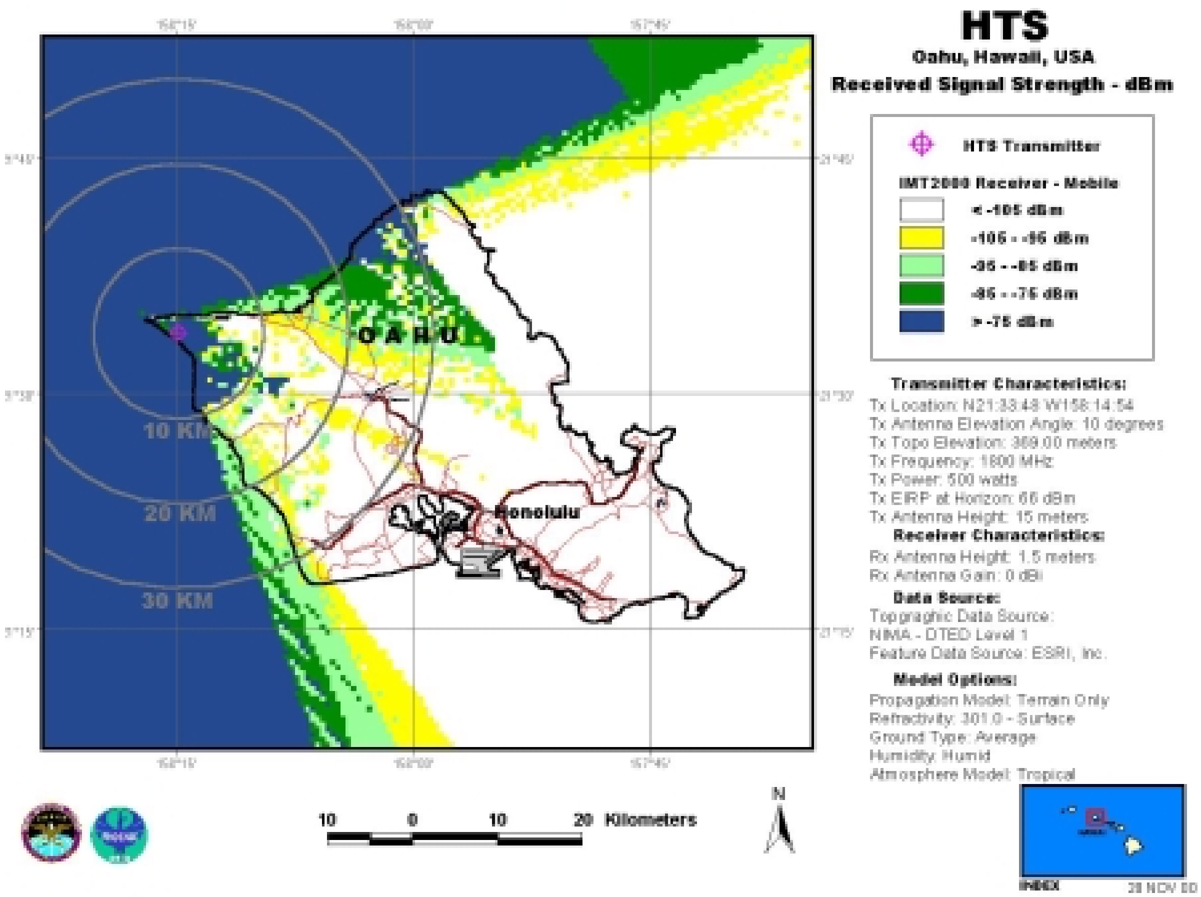

Figure B-12. HTS, Antenna Elevation Angle: 10° Transmitter Power: 500 W, IMT-2000 Mobile Station

As expected, the plots illustrate that impact to IMT-2000 receivers in the far sidelobes and backlobe of the SATOPS antenna is far less than that closer to the mainbeam. This factor should be taken into consideration when exploring mitigation techniques and frequency sharing options. It is also apparent that the benefits realized from raising the minimum elevation angle are primarily in the regions surrounding the mainbeam and first sidelobes.

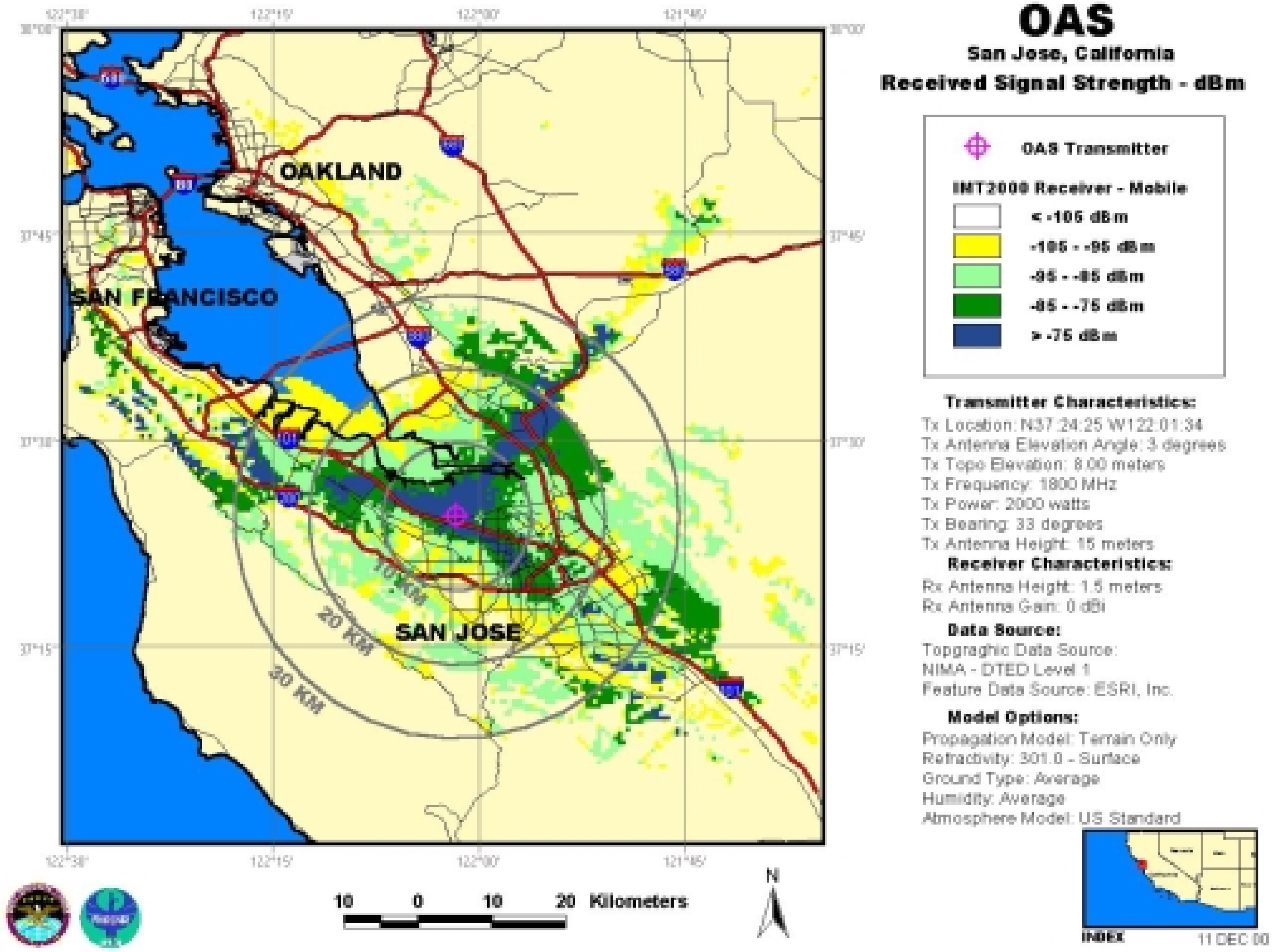

Figure B-13. OAS, Antenna Elevation Angle: 3°, Azimuth 33°, Transmitter Power: 2000 W, IMT-2000 Mobile Station

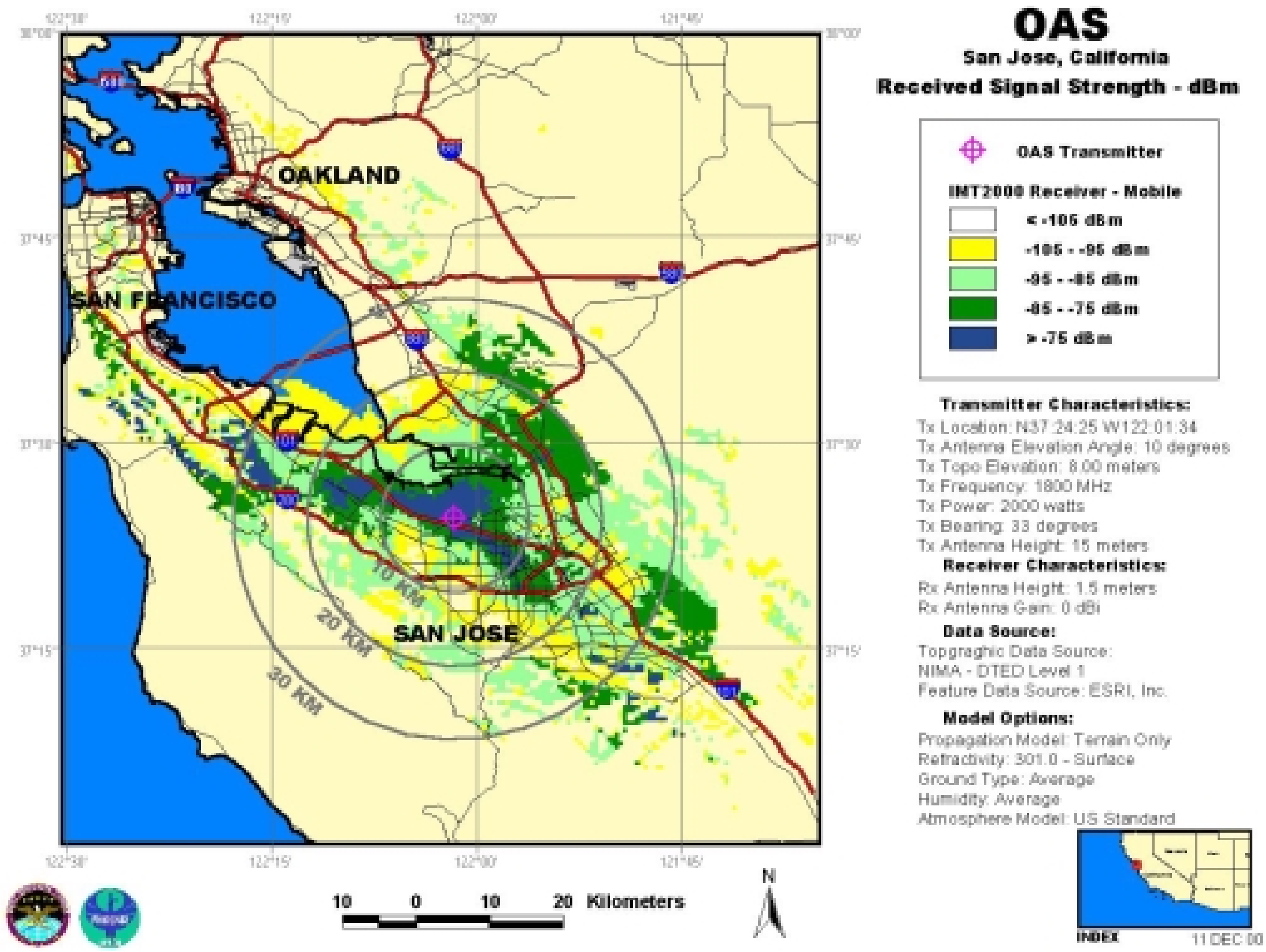

Figure B-14. OAS, Antenna Elevation Angle: 10°, Azimuth 33°, Transmitter Power: 2000 W, IMT-2000 Mobile Station

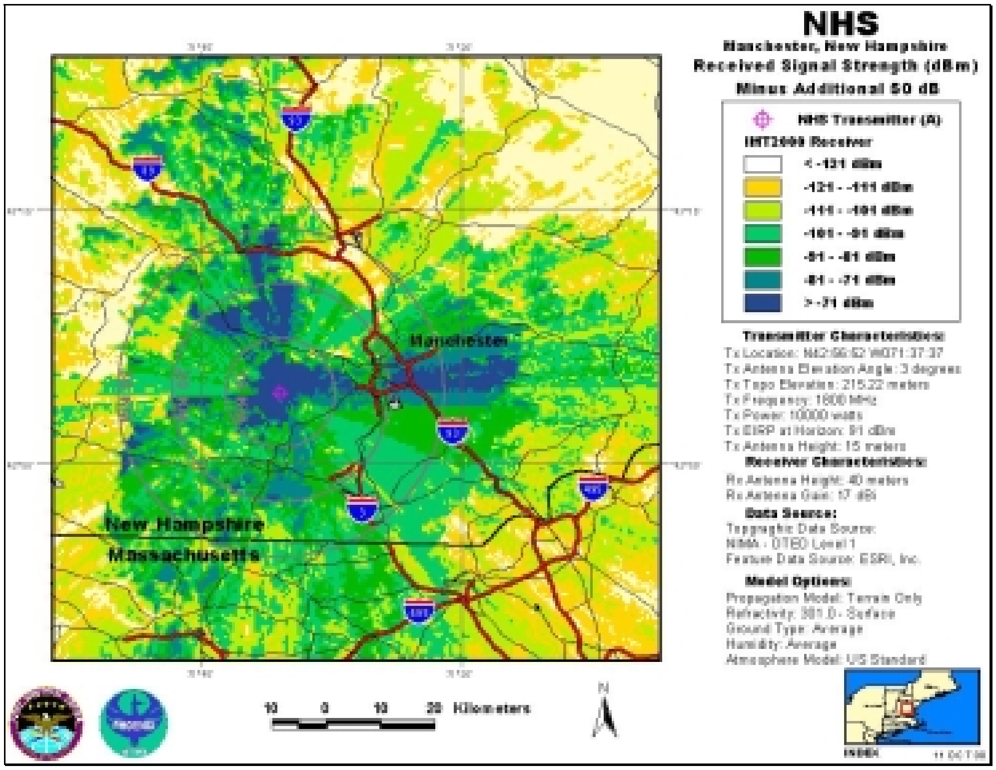

Figure B-15. NHS-A, Antenna Elevation Angle: 3°, Transmitter Power: 10,000 W, IMT-2000 Base Station, Plus an Additional 50 dB of Signal Attenuation

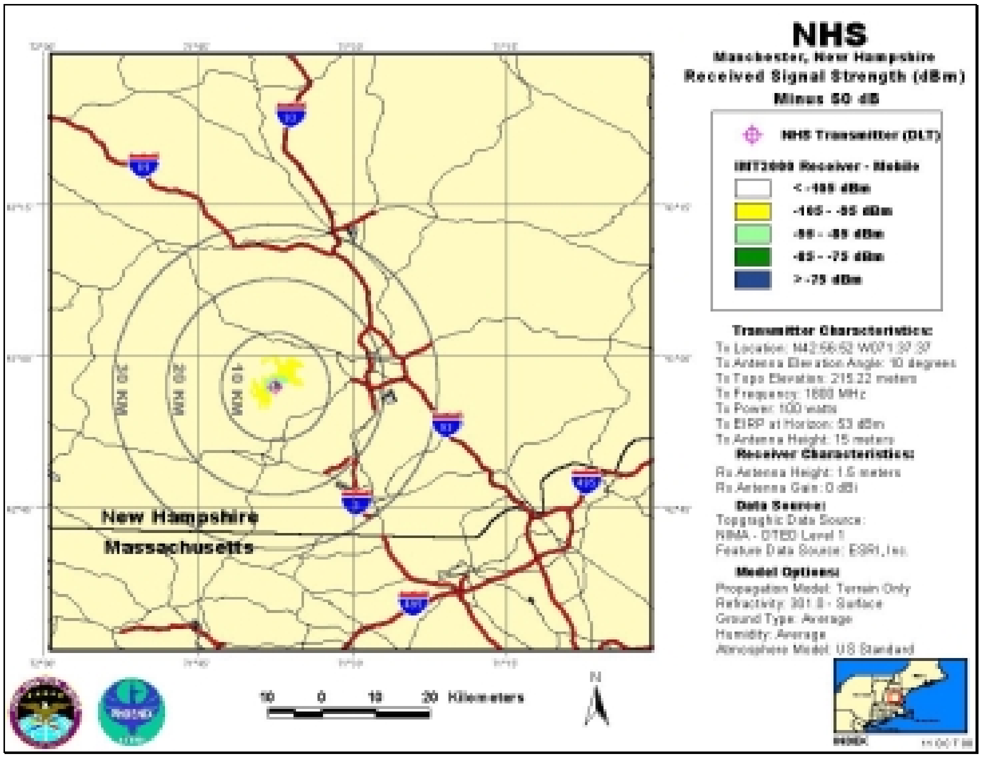

Figure B-16. NHS-DLT, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station, Plus an Additional 50 dB of Signal Attenuation

SATOPS uplink power management, antenna elevation angle restrictions, and frequency off tuning help to reduce the affected area around the SATOPS uplink transmitter. However, if coordination regions on the order of 10 to 20 km are desired, and IMT-2000 specified interference thresholds are to be met, an orders of magnitude decrease in the undesired signal level will be required. Additional measures for reducing the uplink power at the IMT-2000 receiver coupled with power management and antenna restrictions must be implemented to significantly limit the affected area surrounding the uplink site.

B.4.2.1.4 SATOPS Uplink to IMT-2000 Receivers Interference Mitigation Measures

Based upon the results of the signal level predictions, it is apparent that additional signal attenuation is required if sharing between the services is desired. Potential mitigation techniques fall into one of three categories: measures implemented solely by the DoD SATOPS community, measures implemented solely by the IMT-2000 industry, and those techniques that require mutual implementation by both parties. The following measures are presented for discussion and consideration. It is important to note that not all costs of these mitigation techniques have been estimated. Employing any of these techniques would require a cost assessment and could dramatically alter the cost estimates presented earlier. Further analysis is warranted to address viability, cost, and implementation issues.

B.4.2.1.4.1 DoD EMI Mitigation Techniques

Relocation of the SATOPS Uplink Antennas and/or SATOPS Transmission Off-loading. Some of the current SATOPS terminals around the world are located in remote areas such as Diego Garcia and Thule, Greenland. It is expected that these regions will have a relatively low IMT-2000 user density. There are, however, several stations, such as New Hampshire or Sunnyvale, located near population centers. For sites such as these, it may be useful to consider the cost and mission impacts of moving the tracking stations, including antennas, and operations and maintenance personnel to more remote locations with lower population densities that are less desirable from an IMT-2000 market perspective. Similarly, where satisfactory visibility can be achieved, it may be possible that some of the operations currently performed by terminals in populated areas could be off-loaded to more remote terminals. It must be emphasized that relocating tracking stations and their antennas requires both time and additional funding to achieve frequency protection, negotiate international agreements, perform construction, and to acquire and install the SATOPS systems. Based on existing military construction funding rules, Congressional review would be required for each affected site.

Reduction of the Out-of-Beam Energy of the SATOPS Antennas. Assuming that the mainbeam emissions are highly focused in the SATOPS antennas, some control of the radiation in the direction of the victim receivers would be beneficial. The most common approaches to this are (1) antenna elevation angle restrictions and (2) intentional signal blockage and antenna redesign.

***SATOPS Antenna Elevation Angle Restrictions*.** Like power management, restricting the minimum elevation angle serves to limit the power at the horizon and hence reduce the undesired signal into the IMT-2000 receiver. As illustrated in the overlays, a 10-degree minimum elevation angle reduced the size of the affected areas. However, even when coupled with power management, these measures are insufficient to reduce EMI regions to expected acceptable levels.

Signal Blockage and Antenna Redesign. Intentional signal blockage can be achieved via a cylinder surrounding the dish to reduce spillover, modification of the feed, or modification of the illumination taper to reduce sidelobes at the expense of gain.

SATOPS Power Management. SATOPS transmit power capabilities typically vary over a wide range from as low as 100 Watts to as much as 10 kW. The high-power transmissions are typically reserved for emergency operations but are also radiated periodically for system checkout and training. Link closure can typically be achieved at powers in the 100 to 500 Watt range for satellites on orbit and under nominal operating conditions. As indicated in the signal level predictions, power management does not in of itself solve the EMI problem; however, it does reduce the size of the affected regions.

It should be noted that this mitigation technique might not be possible if IMT-2000 emissions cause EMI to satellite receivers and it becomes necessary to increase the power output of the ground terminal to overcome the interference. Further, it should be noted that any increase in the transmitted power, to reduce interference to the satellites, would have adverse effects on any collocated 3G capability.

B.4.2.1.4.2 IMT-2000 EMI Mitigation Techniques

Establishment of Keep-Out Zones. Short of complete frequency separation, there is a potential for EMI to a mobile user (or fixed base station) if it is allowed to operate in proximity to an SATOPS uplink transmitter. The signal level overlays clearly show the potential size of the affected areas. The possibility of some keep-out zone, even if only a few kilometers surrounding the site, should be considered to help mitigate the most challenging close in interactions.

Base Station Antenna Nulling. It is expected that IMT-2000 antenna implementation may be similar to the current cellular/PCS designs; three-direction antenna segments each covering a 120-degree sector. This scheme introduces the possibility to add an additional highly directive antenna in the direction of the SATOPS terminal and to use that signal to null out the received signals on the broadbeam antenna in the direction of the SATOPS terminal. The hole in coverage created by this scheme could then be filled via an alternate antenna at a location such that a mainbeam interaction with the SATOPS terminal is avoided.

Polarization Discrimination. Polarization discrimination mitigation takes advantage of the fact that the mobile signals are linearly polarized, whereas the SATOPS uplinks are circularly polarized. By measuring the received polarization and cross polarizing the IMT-2000 base station to that signal, a significant reduction in interference is achievable (20 dB) with only a 3-dB reduction to the mobile signal. This proposal obviously requires an investment in technology by the IMT-2000 community and may be practical on a limited scale for base stations in specific problem areas.

B.4.2.1.4.3 Mutual EMI Mitigation Techniques

Cooperative scheduling is an attractive EMI mitigation technique that offers a potential benefit if mutual agreement and coordination with the IMT-2000 industry can be achieved. Cooperative scheduling is not unlike band segmentation in that both approaches look toward frequency separation between the systems as a technique for minimizing the potential for EMI. Note however the significant distinction between cooperative scheduling, which assumes sharing of the entire SGLS uplink band via real-time frequency deconfliction, and band segmentation, which assumes separation of systems into distinctly separate portions of the spectrum. Unlike band segmentation, cooperative scheduling addresses EMI issues associated with uplinks to currently flying systems for which only one S-band channel is available for TT&C. In these instances, there is essentially no flexibility in terms of spectrum use from the SATOPS perspective.

Cooperative scheduling takes advantage of the fact that SATOPS operations only use a limited amount of spectrum at any given instant in time. That, coupled with the specific antenna pointing required for a satellite contact, limits the affects on the environment. Therefore, at any instant, only a relatively small portion of the IMT-2000 network maybe affected. The concept behind cooperative scheduling is to allow the IMT-2000 network to dynamically assign spectrum usage to the network around the SATOPS uplink transmissions. This technique would require software enhancements and dynamic switching capabilities for the IMT-2000 systems. It also assumes that the IMT-2000 switching algorithm is fed information on the SATOPS uplink schedule either in advance via pre-coordination, in real-time via landline, or by monitoring the environment for SATOPS signal use. The requirement to pass SATOPS scheduling information to IMT-2000 service providers in turn raises operations securities issues that need to be addressed. While this mitigation technique is not without its challenges, it takes advantage of the SATOPS unique time/frequency use of the electromagnetic spectrum and, therefore, could be one of the more effective techniques to reduce EMI to the IMT-2000 users. This technique will also require channel filters to be installed at US&P sites.

B.4.2.1.5 Summary

Further study is required to quantify the benefit of the aforementioned mitigation measures. Figures B-15 and B-16 are provided to illustrate the benefit of mitigation techniques that provide an additional 50 dB of attenuation in the direction of the victim receiver. Note that under the worst-case conditions for NHS, the affected area improvement is notable but still considerably large.

B.4.2.2 Potential Interference to SATOPS uplinks from IMT-2000

B.4.2.2.1 Assessment Approach

The approach was to calculate the estimated interference environment into a spacecraft receiver based upon the power flux density per square kilometer per Hertz generated by IMT–2000 stations in an urban environment and the population density and urban area sizes visible from the spacecraft. ITU-R Recommendation M.687-2 gives the power flux density per square kilometer per Hertz generated by IMT-2000 base stations and mobile stations in a urban area. This power flux density was derived from an estimation of the spectrum needed for IMT-2000. ITU-R Report M.2023 provides an updated estimate of the spectrum required for IMT-2000. The power flux density used in this assessment was calculated from the updated spectrum requirements using the same procedure as was used in ITU-R Recommendation M.687-2. The power flux density from IMT-2000 base stations in Region 2 (North and South America) was calculated to be 41 $\Phi W/km^2/Hz$. The power flux density from IMT-2000 mobile stations in Region 2 was calculated to be 1 $\Phi W/km^2/Hz$.

In addition to the IMT-2000 base stations in urban areas, some base stations will be deployed in rural areas to serve traffic on major highways and to serve small towns. These rural base stations may actually employ higher transmitter powers than their urban counterparts since they may be required to serve a larger area. The contribution from these rural stations was not considered in this report since there was no estimate available of their numbers. The effect of interference from these stations can only increase the impact on orbiting spacecraft from the IMT-2000 systems.

The size of the world’s urban areas and their populations was estimated by taking data from a variety of sources, including United Nations statistical data and US Census Bureau data. The 2763 most populous urban centers are shown in Figure B-17.

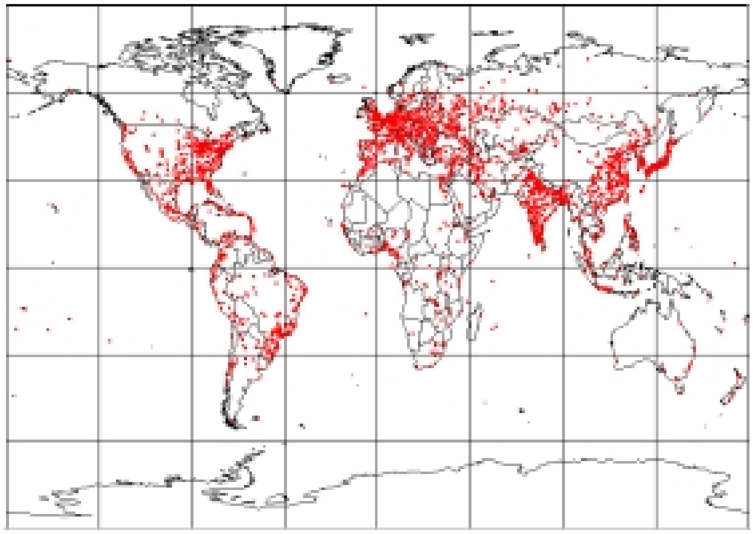

Figure B-17. Most populous urban centers

Although it was possible to identify the estimated populations of the 2763 most populous urban areas, data regarding their size was only available for less than ten percent of the areas. In order to approximate the area of each urban location, the population density of a number of cities can be used, and an average inverse population density can be derived. This is shown in Table B-10, and the resulting value is used in the computations.

Table B-10. Approximate population density (inverse) used in the analysis

City	Size (km^2)	Population (millions)	Ratio (km^2/ millions)
New York	780	7.3	106.8
London	1500	7.0	214.3
Paris	103	2.2	46.8
Berlin	891	3.5	254.6
Mexico	3000	20.9	143.5
Chicago	591	7.8	75.8
Toronto	650	5.0	130.0
Las Vegas	218	1.2	181.7
Average Ratio			144.2

A computer simulation program was developed to calculate the estimated IMT-2000 interference environment into a spacecraft receiver. The orbit shell is defined by a matrix of spacecraft latitude and longitude positions (up to ±90º in latitude, and 360º in longitude). At each position on the orbit shell, the database of cities is searched for those that are visible from the spacecraft. Using their approximated geographic size, the total interfering power density into the spacecraft receiver is calculated from Equation B-1.

$$I(dBW/Hz) = \sum_i \left\{ 10 \cdot \log\left[\left(41\mu W/km^2/Hz \right) \cdot \left(citypop_i \right) \cdot \left(144.2km^2/millions \right) \right] - \left(32.44 + 20 \cdot \log\left(range_i \cdot freq \right) \right) - L_e \right\} \tag{B-1}$$

where

$citypop_i$ = population of the i[th] visible city, in millions
$range_i$ = range to the i[th] visible city, in km
$freq$ = 1800 MHz in all calculations
L_e = environmental losses; 10 dB in all calculations

and, though not shown, values are converted back to linear units before summation.

A typical satellite link budget from a representative Air Force Satellite Control Network (AFSCN) transmitter to a satellite using a common telemetry, tracking, and commanding (TT&C) transponder (the L3–Com model CXS810–C) was used to compute the link margin in the absence of interference from IMT-2000 transmitters. The aggregate interference level from the IMT-2000 environment was then used to compute the net margin.

B.4.2.2.2 Link Margin calculations

Four satellite orbits were chosen for the assessment:

- A 250-kilometer orbit, typical of the Space Transportation System (STS)
- An 833-kilometer orbit, typical of meteorological satellites such as Defense Meteorological Satellite Program (DMSP)
- A 20,200-kilometer orbit, typical of the Global Positioning System (GPS)
- A 35,784-kilometer orbit, typical of geostationary satellites

For the two lowest orbits, two hypothetical AFSCN transmitter powers, 250 W and 2000 W, were used in the assessment. For the other two orbits, only the 2000 W power was used. These power levels may not be the actual powers normally used in AFSCN operations, but are representative of AFSCN capabilities.

The AFSCN uses a variety of antennas ranging in size from 23 ft to 60 ft. For this assessment, a 33-ft antenna with a gain of 41 dBi was selected for the AFSCN station. A spacecraft antenna with a -5 dBi gain was assumed as typical. Propagation losses took into account free-space path loss, cloud loss, rain loss, atmospheric loss, and polarization loss based on the slant-range to the spacecraft. Three AFSCN station elevation angles were used to determine the losses through the earth's atmosphere.

A typical SGLS transponder, the L3 Communications CXS-810C, was used to represent the spacecraft receiver. The spacecraft effective receiver system temperature was 798° Kelvin. The threshold powers were calculated for the Command service and for the Carrier service based on the use of a 0.3 modulation index for the Command and Ranging signals.

Link margin calculations considering IMT-2000 interference were based on the IMT-2000 traffic loading characteristics of ITU Region 2 (the Americas). Since the power densities per square kilometer per Hertz from the other regions differed by less than 1 dB for the Base Stations and by approximately 3 dB for the Mobile Stations, it is reasonable to assume that the Region 2 values are indicative of the interference environment worldwide.

An example of the link budget and the net margin calculations is shown in Table B-11. The results of the link margin calculations are shown in Tables B-12 through B-19. Analysis results for the ranging function are not shown in these tables. The degradation to the command capability is always more severe than to the ranging capability. The effect of interference on ranging is to increase the time required to integrate the pseudonoise code in order to determine the range. Separate tables are shown for interference from mobile stations and base stations for each of the years 2003, 2006, and 2010 as well as for a future full buildout of the IMT-2000 system.

Table B-11. Typical Link Budget

Freq	1800	MHz		
TX Power	2000	Watts		
TX Power	63	dBm		
TX EIRP	105	dBm		
TX Ant Dia	33	Ft		
TX Ant Beamwidth	1	Deg		
TX Ant Gain	42	dBi		
Orbit Height	35784	Kilometers		
Elevation Angle	3	Deg		
Mean Earth Radius	6378	Kilometers		
Slant Range	42220	Kilometers		
Space Loss	190	dB		
Cloud Loss	0.0	dB		
Rain Loss	0.5	dB		
Atmospheric Loss	0.6	dB		
Polarization Loss	0.5	dB		
Scintillation Loss	0.0	dB		
Rx Antenna Gain	-5	dB		
Rx Antenna Temp	300	Deg K		
Rx Diplexer Loss	0.3	dB		
Rx Coupler Loss	1	dB		
Rx Cable Loss	2	dB		
Rx Cable Temp	170	Deg K		
Total Rx Line Loss	3	dB		
Receiver NF	5	dB		
Receiver Temp	627	Deg K		
Eff Rx Ant Temp	171	Deg K		
Rx System Temp	798	Deg K		
Rx System Temp	29	dBK		
Rx System Gain	-5	dB		
Rx G/T	-34	dB/K		
Rx Isotropic Carrier Pwr	-95	dBm		
	CMD	Carrier	Ranging	
Mod Index	0.3		0.3	
Mod Loss	-14	-1		
Threshold Power for a CXS810-C	-99	-125		dBm
Data Rate	2000			
Link Margin	4	30		
System Noise	-198	-198		dBW/Hz
IMT-2000 Interference + System Noise	-190	-190		dBW/Hz
Net Margin	-5	22		

Table B-12. Interference from IMT-2000 Mobile Stations in 2003

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	13.5	40.0
			5 deg	25.0	51.4	15.0	41.4
			10 deg	27.7	54.1	17.7	44.1
		2000 W	3 deg	32.6	59.0	22.6	49.0
			5 deg	34.0	60.4	24.0	50.4
			10 deg	36.7	63.1	26.7	53.1
DMSP	833 km	250 W	3 deg	17.4	43.8	13.7	40.1
			5 deg	18.3	44.8	14.6	41.1
			10 deg	20.0	46.4	16.3	42.7
		2000 W	3 deg	26.4	52.8	22.7	49.1
			5 deg	27.4	53.8	23.7	50.1
			10 deg	29.0	55.5	25.3	51.8
GPS	20,200 km	2000 W	3 deg	8.0	34.4	7.7	34.1
			5 deg	8.4	34.9	4.2	34.6
			10 deg	8.9	35.3	4.5	35.1
GEO	35,784 km	2000 W	3 deg	3.8	30.2	3.7	30.1
			5 deg	4.2	30.6	4.2	30.6
			10 deg	4.6	31.0	4.5	31.0

Table B-13. Interference from IMT-2000 Mobile Stations in 2006

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	6.5	33.0
			5 deg	25.0	51.4	8.0	34.4
			10 deg	27.7	54.1	10.7	37.1
		2000 W	3 deg	32.6	59.0	15.6	42.0
			5 deg	34.0	60.4	17.0	43.4
			10 deg	36.7	63.1	19.7	46.1
DMSP	833 km	250 W	3 deg	17.4	43.8	6.7	33.1
			5 deg	18.3	44.8	7.7	34.1
			10 deg	20.0	46.4	9.3	35.7
		2000 W	3 deg	26.4	52.8	15.7	42.1
			5 deg	27.4	53.8	16.7	43.1
			10 deg	29.0	55.5	18.3	44.8
GPS	20,200 km	2000 W	3 deg	8.0	34.4	6.8	33.2
			5 deg	8.4	34.9	7.2	33.7
			10 deg	8.9	35.3	7.7	34.1
GEO	35,784 km	2000 W	3 deg	3.8	30.2	3.5	29.9
			5 deg	4.2	30.6	3.9	30.4
			10 deg	4.6	31.0	4.3	30.8

Table B-14. Interference from IMT-2000 Mobile Stations in 2010

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	4.0	30.4
			5 deg	25.0	51.4	5.4	31.8
			10 deg	27.7	54.1	8.1	34.5
		2000 W	3 deg	32.6	59.0	13.0	39.4
			5 deg	34.0	60.4	14.5	40.9
			10 deg	36.7	63.1	17.1	43.6
DMSP	833 km	250 W	3 deg	17.4	43.8	4.1	30.6
			5 deg	18.3	44.8	5.1	31.5
			10 deg	20.0	46.4	6.8	33.2
		2000 W	3 deg	26.4	52.8	13.2	39.6
			5 deg	27.4	53.8	14.1	40.6
			10 deg	29.0	55.5	15.8	42.2
GPS	20,200 km	2000 W	3 deg	8.0	34.4	6.0	32.4
			5 deg	8.4	34.9	6.5	32.9
			10 deg	8.9	35.3	6.9	33.4
GEO	35,784 km	2000 W	3 deg	3.8	30.2	3.3	29.7
			5 deg	4.2	30.6	3.7	30.2
			10 deg	4.6	31.0	4.1	30.6

Table B-15. Interference from IMT-2000 Mobile Stations at Full Buildout

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	3.5	30.0
			5 deg	25.0	51.4	5.0	31.4
			10 deg	27.7	54.1	7.7	34.1
		2000 W	3 deg	32.6	59.0	12.6	39.0
			5 deg	34.0	60.4	14.0	40.4
			10 deg	36.7	63.1	16.7	43.1
DMSP	833 km	250 W	3 deg	17.4	43.8	3.7	30.1
			5 deg	18.3	44.8	4.6	31.1
			10 deg	20.0	46.4	6.3	32.7
		2000 W	3 deg	26.4	52.8	12.7	39.1
			5 deg	27.4	53.8	13.7	40.1
			10 deg	29.0	55.5	15.3	41.8
GPS	20,200 km	2000 W	3 deg	8.0	34.4	5.8	32.2
			5 deg	8.4	34.9	6.3	32.7
			10 deg	8.9	35.3	6.8	33.2
GEO	35,784 km	2000 W	3 deg	3.8	30.2	3.3	29.7
			5 deg	4.2	30.6	3.7	30.1
			10 deg	4.6	31.0	4.1	30.5

Table B-16. Interference from IMT-2000 Base Stations in 2003

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	-3.3	23.1
			5 deg	25.0	51.4	-1.9	24.5
			10 deg	27.7	54.1	0.8	27.2
		2000 W	3 deg	32.6	59.0	5.7	32.1
			5 deg	34.0	60.4	7.1	33.6
			10 deg	36.7	63.1	9.8	36.3
DMSP	833 km	250 W	3 deg	17.4	43.8	-3.2	23.2
			5 deg	18.3	44.8	-2.2	24.2
			10 deg	20.0	46.4	-0.5	25.9
		2000 W	3 deg	26.4	52.8	5.9	32.3
			5 deg	27.4	53.8	6.8	33.2
			10 deg	29.0	55.5	8.5	34.9
GPS	20,200 km	2000 W	3 deg	8.0	34.4	2.9	29.3
			5 deg	8.4	34.9	3.4	29.8
			10 deg	8.9	35.3	3.8	30.3
GEO	35,784 km	2000 W	3 deg	3.8	30.2	1.7	28.1
			5 deg	4.2	30.6	2.2	28.6
			10 deg	4.6	31.0	2.6	29.0

Table B-17. Interference from IMT-2000 Base Stations in 2006

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	-10.3	16.1
			5 deg	25.0	51.4	-8.9	17.5
			10 deg	27.7	54.1	-6.2	20.2
		2000 W	3 deg	32.6	59.0	-1.3	25.1
			5 deg	34.0	60.4	0.2	26.6
			10 deg	36.7	63.1	2.8	29.3
DMSP	833 km	250 W	3 deg	17.4	43.8	-10.2	16.3
			5 deg	18.3	44.8	-9.2	17.2
			10 deg	20.0	46.4	-7.5	18.9
		2000 W	3 deg	26.4	52.8	-1.1	25.3
			5 deg	27.4	53.8	-0.2	26.3
			10 deg	29.0	55.5	1.5	27.9
GPS	20,200 km	2000 W	3 deg	8.0	34.4	-4.1	22.3
			5 deg	8.4	34.9	-3.6	22.8
			10 deg	8.9	35.3	-3.1	23.3
GEO	35,784 km	2000 W	3 deg	3.8	30.2	-1.7	24.7
			5 deg	4.2	30.6	-1.2	25.2
			10 deg	4.6	31.0	-0.8	25.6

Table B-18. Interference from IMT-2000 Base Stations in 2010

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	-12.9	13.6
			5 deg	25.0	51.4	-11.4	15.0
			10 deg	27.7	54.1	-8.7	17.7
		2000 W	3 deg	32.6	59.0	-3.8	22.6
			5 deg	34.0	60.4	-2.4	24.0
			10 deg	36.7	63.1	0.3	26.7
DMSP	833 km	250 W	3 deg	17.4	43.8	-12.7	13.7
			5 deg	18.3	44.8	-11.8	14.7
			10 deg	20.0	46.4	-10.1	16.3
		2000 W	3 deg	26.4	52.8	-3.7	22.7
			5 deg	27.4	53.8	-2.7	23.7
			10 deg	29.0	55.5	-1.1	25.4
GPS	20,200 km	2000 W	3 deg	8.0	34.4	-6.6	19.8
			5 deg	8.4	34.9	-6.2	20.3
			10 deg	8.9	35.3	-5.7	20.7
GEO	35,784 km	2000 W	3 deg	3.8	30.2	-4.2	22.2
			5 deg	4.2	30.6	-3.8	22.6
			10 deg	4.6	31.0	-3.4	23.0

Table B-19. Interference from IMT-2000 Base Stations at Full Buildout

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	-13.3	13.1
			5 deg	25.0	51.4	-11.9	14.5
			10 deg	27.7	54.1	-9.2	17.2
		2000 W	3 deg	32.6	59.0	-4.3	22.1
			5 deg	34.0	60.4	-2.9	23.6
			10 deg	36.7	63.1	-0.2	26.3
DMSP	833 km	250 W	3 deg	17.4	43.8	-13.2	13.2
			5 deg	18.3	44.8	-12.2	14.2
			10 deg	20.0	46.4	-10.5	15.9
		2000 W	3 deg	26.4	52.8	-4.1	22.3
			5 deg	27.4	53.8	-3.2	23.2
			10 deg	29.0	55.5	-1.5	24.9
GPS	20,200 km	2000 W	3 deg	8.0	34.4	-7.1	19.3
			5 deg	8.4	34.9	-6.6	19.8
			10 deg	8.9	35.3	-6.2	20.3
GEO	35,784 km	2000 W	3 deg	3.8	30.2	-4.7	21.7
			5 deg	4.2	30.6	-4.3	22.2
			10 deg	4.6	31.0	-3.9	22.6

B.4.2.2.3 Summary

Interference from IMT–2000 base stations is much more severe than from the mobile stations, but both represent potentially significant interference to SATOPS. The potential for interference is most evident at the low orbits for many of the less favorable operational scenarios. On average, the geostationary orbit interference will be quite severe. The negative net margins predicted indicate that cochannel sharing with IMT-2000 base stations may not be feasible for some systems even in the early stages of IMT-2000 implementation if the predicted levels of interference are realistic. Carrying that assumption forward for the 2006 timeframe, interference in all orbits is expected. Sharing with mobile stations will be less of a problem. Increasing transmitter power will minimize the interference on the uplink, but will increase interference to IMT-2000 receivers. Therefore, this has little practical benefit.

The satellite characteristics and performance requirements used in this assessment are representative of typical characteristics of US military space systems. For specific space programs the actual characteristics may vary. Also, SATOPS terminal values used were also considered to be representative of current systems, but future systems may use smaller antennas and may not have the power capability assumed for this analysis. Therefore, results will vary as specific ground and space systems differ, but this analysis is indicative of the magnitude of the problem.

Because this is a key element in any decision, a more comprehensive study is necessary. As stated previously, the assessment results presented in this report are based on a near worst-case scenario. Interference caused by introducing 3G users into the 1755-1850 MHz band can potentially have severe impacts to DoD satellite operations. DoD will continue to examine the impacts by conducting more comprehensive assessments to determine the impacts to DoD satellite missions.

An estimate of the magnitude of the variation in the link results may be determined by using the variations given in Table B-20.

Table B-20. Tolerances on Link Margin Calculation

Factor	Value Used	Upper Bound	Lower Bound	Explanation
EIRP	111.5 dBm	116 dBm	104	EIRP is different at different RTS due to antenna size; Modernization contract for 2004 and beyond is limited to 104 dam at most RTS, 110 dBM at 4 sites worldwide
Receive Antenna Gain	-5 dBi	0 dBi	-17 dBi	Spacecraft antenna patterns differ; most contain null between Zenith and nadir. Depends on definition of gain at edge of coverage
Receive Losses	3.3 dB	5 dB	1 dB	Depends on spacecraft design; i.e coupler or no coupler, diplexer loss, cable length.
Receiver NF	5.0 dB	6.0 dB	2.0 dB	Depends on vendor and state of the art when that spacecraft was built
Threshold Sensitivity (at 2Kbps & Mod index of .6	Cmd: -104.7dBm Carrier: -124.8 dBm	-98 dBm -120dBm	-132dBm -126dBm	Depends on vendor and state of the art when that spacecraft was built. Also directly dependent on mod index and data rate
Mod index	0.3	1.0	0.3	Depends on System design for a particular program
Mod Loss	--14 dB	-2.3dB	-14 dB	Depends on mod index
Data Rate Effect of data Rate on margin	2.0 Kbps	1.0 Kbps 3 dB	10 Kbps -7 dB	Depends on System design for a particular program

B.5 OPTION 2 – BAND SEGMENTATION/PARTIAL BAND SHARING

B.5.1 Operational Impact

In general, all of the operational impact statements regarding the full band sharing and denied spectrum access apply to those portions of the band segmented for non-government use. By retaining 1755-1805 MHz for exclusive US Government use, SGLS channels 12 through 20 would potentially become shared with non-government users. Should this be implemented, assured access would still be required for the entire 1755-1850 MHz band (including the 1805-1850 MHz portion) to support the on-orbit assets utilizing the shared spectrum. Without such access, TT&C functions would be jeopardized and resultant satellite/payload and mission failure could occur as described above.

Assuming SATOPS access to the non-government portion of the spectrum is retained, the mitigation techniques and operational impacts associated with the full band sharing option would apply. This includes those issues associated with impact to the SATOPS uplink from IMT-2000 noise levels emanating from the surface of the earth as a function of the IMT-2000 build out schedule. Impacts of course would be limited to those satellite systems operating in the spectrum occupied by non-government users. In a few rare exceptions, systems possessing two TT&C frequencies may be able to mitigate RFI by operating on a channel in the government-only portion of the band if applicable. In addition to the aforementioned mitigation options, it may be necessary to implement SATOPS transmitter filtering on those exclusive government channels adjacent to the non-government spectrum.

The satellite systems currently utilizing or scheduled to use SGLS channels 12-20 include DSCS, Milstar, FLTSAT, DMSP, ISR, TE, Advanced EHF, Wideband Gapfiller Satellite (WGS), UHF Follow-On (UFO), SBIRS, and MSX. For the satellites ready for launch or already on-orbit, their uplink frequencies are fixed. Inability to use those frequencies without interference will eventually cause mission failure. DSCS, Milstar, and UFO satellites already built or on-orbit are expected to remain operational past 2017. Mission capabilities potentially impacted include communications systems and space-based surveillance systems. Therefore, in the 2010 time frame, there will still be a large number of on-orbit satellites that require SGLS channel 12-20 for operations.

B.5.2 1755-1805 MHz Retained – Technical Assessment

This option would allow retention of SATOPS functions in the 1761-1805 MHz band (SGLS channels 1-11) and IMT-2000 operations in the 1805-1850 MHz band. This option would reduce the potential for electromagnetic interference (EMI) by maintaining a frequency separation between transmitters and receivers. Given that SATOPS functions currently support satellites operating throughout the 1761-1842 MHz band, a segmentation scheme alone would reduce but not eliminate the potential for EMI to IMT-2000 receivers. The potential for EMI would remain for those systems operating in the IMT-2000 portion of the spectrum (SGLS channels 12-20) until the requirement to support such satellites no longer exists and the band can be vacated. In some instances however, satellite programs are supported via two S-band channels. This introduces the added benefit of frequency flexibility and provides an EMI mitigation possibility if one of the two channels lies outside the IMT-2000 spectrum. Finally, for those satellites that have not yet been launched, the opportunity exists to outfit the vehicle with SATOPS transponders in the band segment allocated for TT&C.

To illustrate the impact of off-tuning the SATOPS uplink and IMT-2000 receivers on the relative size of the coordination regions, three sample overlays were generated for the New Hampshire B terminal operating at 2.5 kilowatts with a 10 degrees elevation angle. Figures B-18 through B-20 illustrate the coordination regions for IMT-2000 base station receivers assuming frequency separations of 4, 8, and 12 MHz respectively (1, 2, and 3 SATOPS uplink channels). Beyond 12 MHz, the uplink emission rolls off gradually such that additional frequency separation yields minimal benefit.

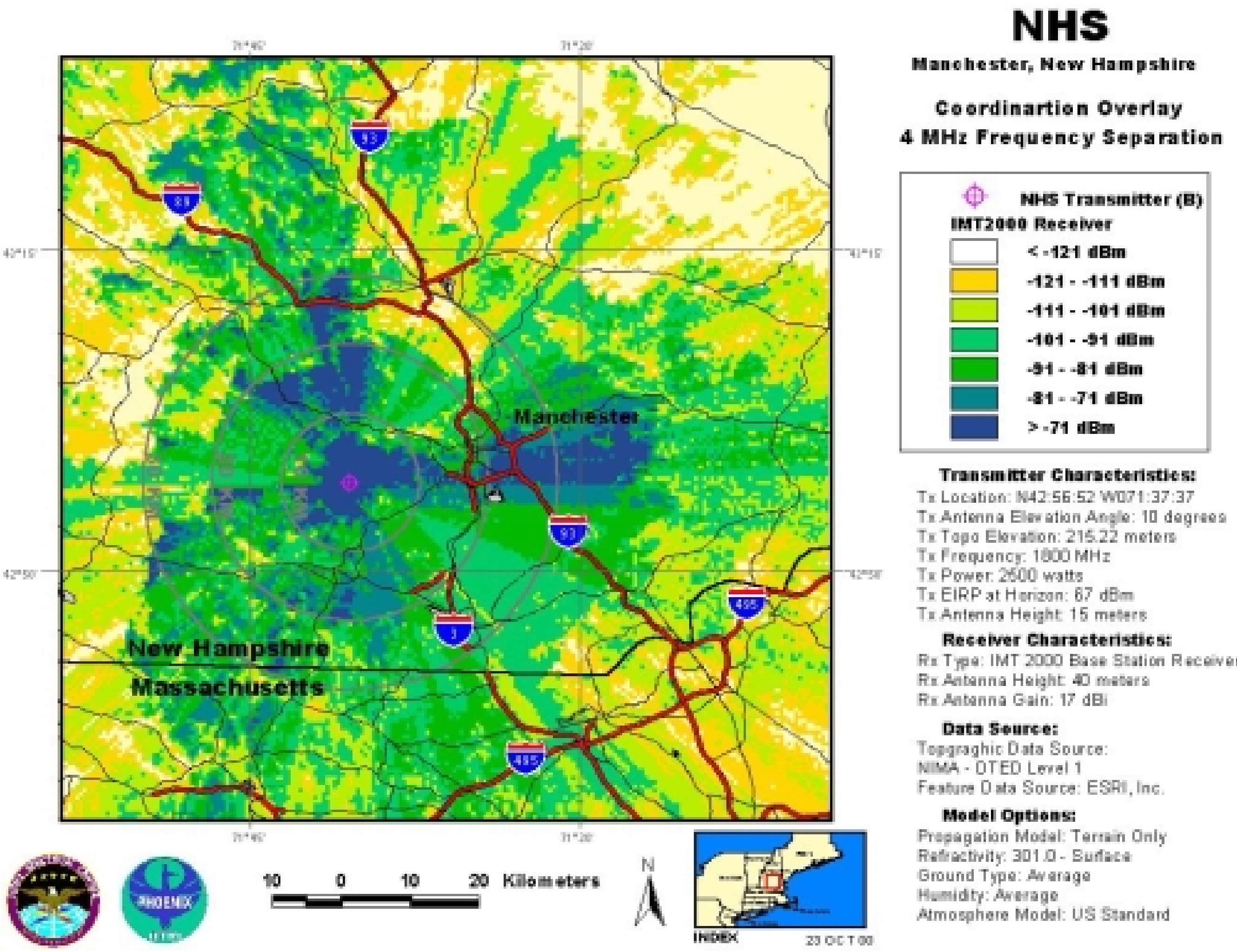

Figure B-18. Coordination Overlay for 4-MHz Frequency Separation

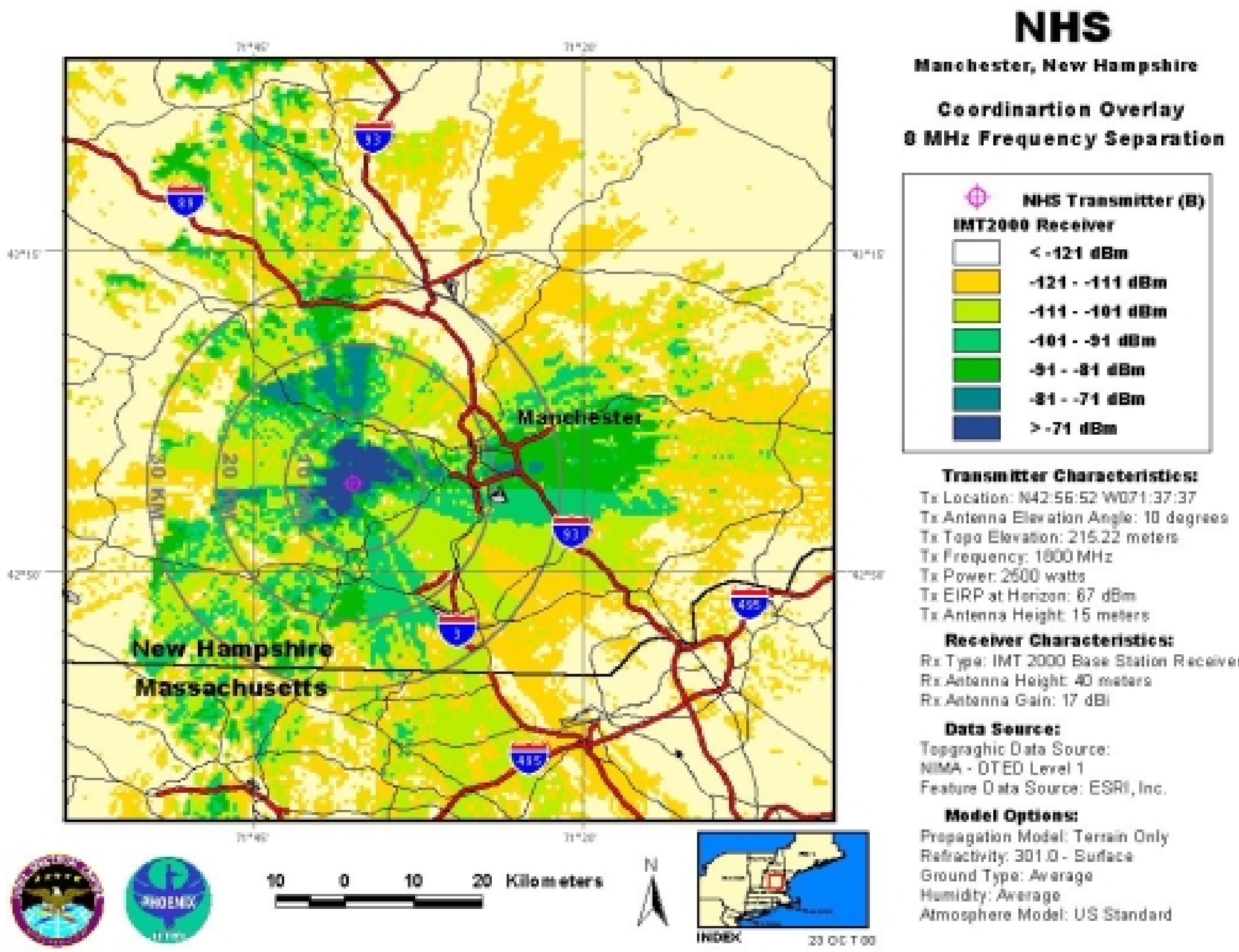

Figure B-19. Coordination Overlay for 8-MHz Frequency Separation

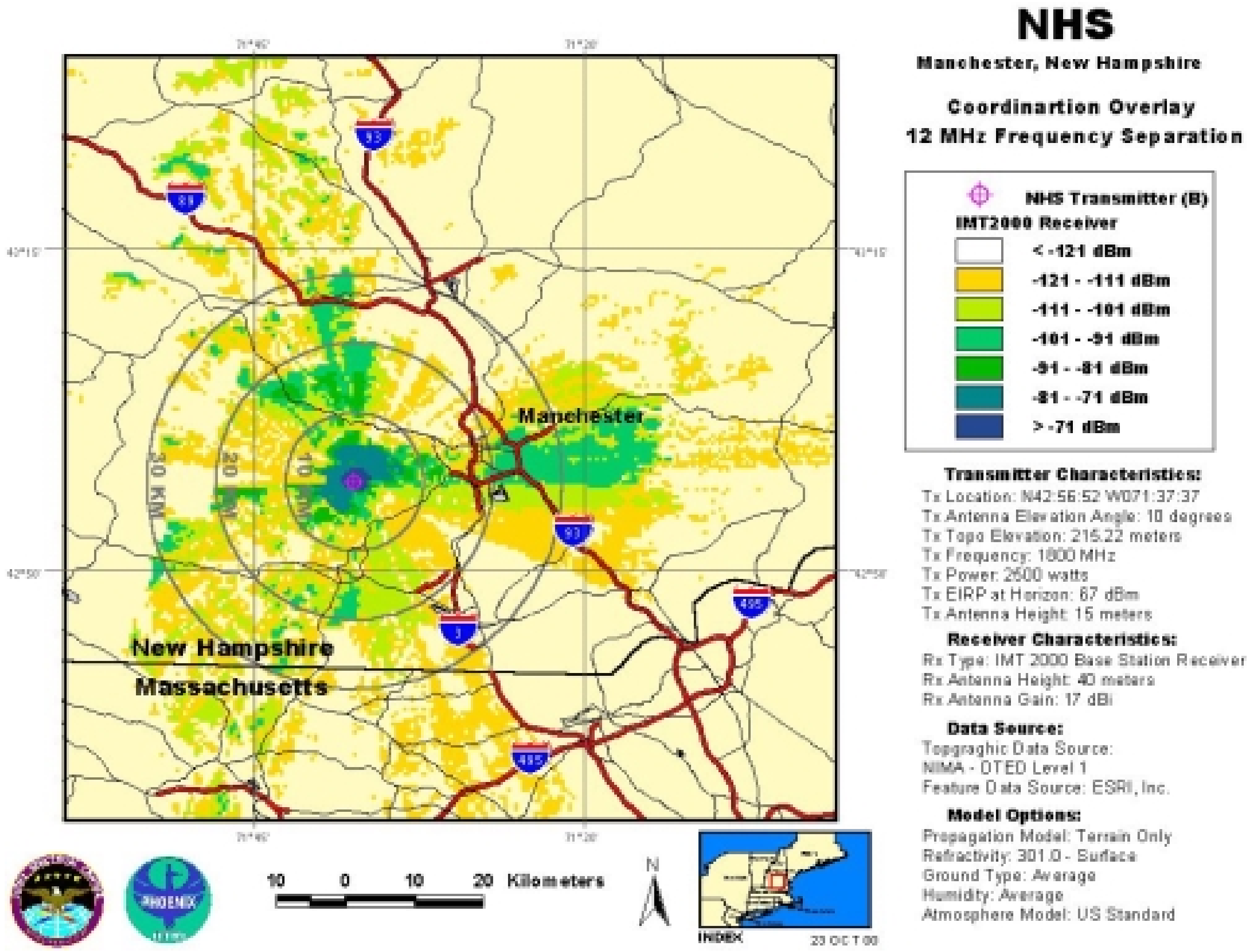

Figure B-20. Coordination Overlay for 12-MHz Frequency Separation

As can be viewed from the overlays, frequency separation clearly reduces the coordination regions, however, like other mitigation techniques discussed, it does not singly provide sufficient isolation between the systems to eliminate the potential for EMI. The limited benefit achieved through off-tuning is reflective of the typically wide/unfiltered emission spectra in the current SGLS signal structure, which is in part due to the unwanted spectral components generated via a class C amplifier. Even with a band segmentation scheme additional filtering of the AFSCN terminals will be required to mitigate interference to the IMT-2000 systems in the adjacent band. It is expected that the more spectrally efficient signal structures that are being considered for future SATOPS uplinks would yield greater benefit in a band segmentation scheme.

B.5.3 1790-1850 MHz Retained – Technical Assessment

This option would allow retention of SATOPS functions in the 1790-1842 MHz band (SGLS channels 8-20) and IMT-2000 operations in the 1755-1790 MHz band. The effects of this option are similar to that of Option 2, but a different set of SGLS channels would be affected. Systems operating on SGLS channels 1-7 would continue to require support and the potential for EMI would remain until the requirement to support such satellites no longer exists.

B.6 OPTION 3 – PARTIAL BAND SEGMENTATION/OTHER BAND COMBINATION

B.6.1 Operational Impact

This band sharing scheme involves a phased-in approach granting non-government access to the 1755-1780 MHz portion of the spectrum in 2006 and access to the 1780-1790 MHz portion of the spectrum in 2010. By retaining 1790-1850 MHz for exclusive US Government use, SGLS channels 1-7 would potentially become shared with non-government users.

Under this option, there is no impact to SATOPS functions in the 2003 timeframe. By 2006, assured access to 1755-1780 MHz portion of the spectrum for SATOPS is required to conduct TT&C for those on-orbit assets operating in the affected portions of the band. Without such access, TT&C functions in channels 1-7 would be jeopardized and resultant satellite/payload and mission failures associated with denied SATOPS spectrum access and SATOPS uplink EMI would occur. The same is true for those systems in the 1780-1790 MHz portion of the spectrum (channels 6 and 7) in 2010.

The satellite systems currently using or scheduled to use SGLS channels 1-5 in the 1755-1780 MHz portion of the band include NATO/Skynet, GFO, ISR, DMSP, and SBIRS. The potential interference from NATO/Skynet, DMSP, and SBIRS operations can be reduced by use of their alternate channel; however, Advanced EHF and GFO lack an alternate channel. Mission capabilities potentially impacted include critical US Armed Forces communications and ISR capabilities.

In 2010, SGLS channels 1-7 would be impacted. Like the other band segmentation options, a lack of assured access to this spectrum for SATOPS functions and degradation to the uplink will lead to satellite/payload and mission failure. The impacts from RFI mitigation options and IMT-2000 uplink EMI parallel those in the previous band segmentation discussions. The satellite systems currently using or scheduled to use SGLS channels 1-7 include those mentioned above, plus those using channels 6 and 7: GPS, DMSP, NPOESS, and SBIRS.

B.6.2 Technical Assessment

If a partial band segmentation option combined with migration of some satellite operations to another band is selected, the technical assessments discussed above would apply to the portion of the band retained for SATOPS. The technical assessment presented in section B.7.2 would apply to the SATOPS migrated to another band.

B.7 OPTION 4 – VACATE 1755-1850 MHZ

In addition to considering sharing possibilities between IMT-2000 and DoD systems, the identification and assessment of candidate frequency bands for the potential migration of existing and planned DoD S-band SATOPS uplink functions is required. This section discusses the issues associated with a migration from the current SGLS 1761-1842 MHz band to the band referred to as Unified S-Band (2025-2110 MHz). It should be noted that total loss of the band is not possible for space systems until at least 2017 or beyond.

The following are critical assumptions/conditions used when considering the migration of current DoD satellite operations to an alternate frequency band:

- Launch, early orbit, and anomaly (LEO&A) resolution support are critical functions that must be maintained throughout the life of a spacecraft
- Given the current implementations, S-band is uniquely suited for conducting critical, non-routine SATOPS functions
- Mission capability provided to end users by US national security space systems will not be degraded. The government will maintain assured access to the 1755-1850 MHz band to satisfy mission objectives until the last 1755-1850 MHz satellite is no longer functioning. This may continue until 2030.
- Domestic regulatory provisions will be implemented so that the DoD has assured access to the 2025-2100 MHz band for Launch, Early Orbit Operations and Anomaly Resolution (LEO&A), and other operations currently operating in the 1755-1850 MHz band. Specifically, the Broadcast Auxiliary Service (BAS) or Electronic News Gathering (ENG) services at transportable and mobile locations shall not claim protection from DoD operations which have been migrated to the 2025-2100 MHz band.

- The electromagnetic compatibility (EMC) between SATOPS uplink systems and incumbent users of the spectrum must be at least equal to that which currently exists in the SGLS frequency band
- Time must be allotted to make an orderly transition

B.7.1 Operational Impact

As indicated, SATOPS functions are absolutely critical for the control and maintenance of the spacecraft. Without alternate spectrum to command the satellite, spacecraft and payload failure would result. Without the use of SGLS in the US&P after 2003, there would be eventual mission failure for a wide range of satellites as described in Option 1. Specific mission functions impacted include missile warning, navigation, military communications, weather, and intelligence; surveillance and reconnaissance; R&D; and international systems.

Without the use of SGLS in 2006, similar results would occur, as insufficient time would be allotted for launching sufficient dual band satellite capabilities and off-loading TT&C functions to non-US sites would not achieve the desired connectivity. All of the systems identified in 2003 would be impacted in 2006, including: missile warning, navigation, military communications, weather, and intelligence; surveillance and reconnaissance; R&D; and international systems. Even with assured spectrum assess, uplink EMI will impact some spacecraft command reliabilities, particularly at the LEO and MEO orbits.

By 2010, there still will be a large number of on-orbit satellites that will require SGLS for operations. The operational impact for Advanced EHF, DSCS, Milstar, DSP, UFO, and GPS of turning off SGLS in 2010 would be the same as turning it off in 2003. These programs will require SGLS past 2017. The FLTSAT, MSX, R&D, and NATO/Skynet programs will have reached end of life, therefore there should be minimal to no impact to these programs. The satellites still on orbit requiring SGLS during this time frame cannot be adequately supported by non-US&P ground sites and therefore would suffer loss of their mission should the US Government be required to vacate 1755-1850 MHz by 2010.

B.7.1.1 GPS

Specific operational impacts associated with the potential loss of various DoD satellites is provided in the next subsections.

Civilian

- Loss of navigation and timing on land, sea, and air

Military

- Loss of navigation for military applications
- Loss of GPS aided/guided munitions
- Loss of GPS aided/guided manned/unmanned aerial platforms
- Loss of GPS aided/guided manned/unmanned land-based platforms
- Loss of GPS aided/guided manned/unmanned seaborne platforms
- Loss of GPS aided/guided manned/unmanned submarine platforms
- Loss of CSEL used in search and rescue (SAR) and all other SAR-related missions

Time Transfer Impact

- Loss of global synchronization for a wide range of military and civilian systems
- Increased risk during aerial refueling rendezvous

Civilian

- Loss of commercial and private aircraft navigational data increasing risks to safety of flight
- Loss of required navigational accuracy and signal availability to a huge number of other civil users like geo-spatial surveying, emergency vehicle dispatch, agricultural crop rotations, oil/petroleum exploration and mapping, and wildlife locations

Timing Synchronization

- A significant number of users of commercial applications require precise (GPS) timing.
- Loss of the required precise timing would severely impact Personnel Communications Services capabilities and worldwide financial institutions' computer operations (including automatic bank machines)

B.7.1.2 DSCS

- Loss of launch and early orbit capabilities for the remaining DSCS satellites
- Loss of platform control and the Single Channel Transponder (SCT) capability for DSCS
- Severe impact to DoD capability to communicate at all levels of conflict

B.7.1.3 Milstar

- Severe impact to DoD capability to communicate at all levels of conflict
- Loss of capability to perform emergency recovery

B.7.1.4 DSP

- Degradation of space based missile warning capability, critical to national security

B.7.1.5 MSX

- Loss of capability to collect data on deep space orbits of military and commercial satellites
- Loss of its unique capability to revisit (sightings) on militarily significant objects
- Impacts ability to reduce the number of lost satellites
- Increases risk to the space operations (space shuttle and other satellites) due to undetected/lost space objects

B.7.1.6 DMSP

- Loss of capability to monitor and predict regional and global weather patterns, including the presence of severe thunderstorms, hurricanes, and typhoons
- Loss of imagery of cloud cover
- Loss of moisture and temperature measurement capability
- Loss of capability to assess the impact of the ionosphere on early warning radar systems and long-range communications
- Loss of capability to monitor global auroral activity and to predict the effects of the space environment on military satellite operations
- Loss of support to civilian weather bureau

- Loss of direct support to battlefield units

B.7.1.7 NATO/Skynet

- Unable to continue to support longstanding international agreements
- Unable to perform backup satellite control of the UK's Skynet 4 constellation

B.7.1.8 FLTSAT/UFO

- Degradation of capability to perform anomaly resolution, including loss of capability to recover from a failure of normal nadir pointing, causing loss of mission capability
- Loss of critical communications for fleet operations and DoD support for GBS

B.7.1.9 GFO

- Loss of platform control for GFO satellite, causing loss of mission capability
- Loss of capability to measure ocean surface heights

B.7.1.10 RESEARCH AND DEVELOPMENT SATELLITES

- Loss of platform control and mission data for the CORIOLIS satellite would result in loss of early capability to measure wind surface speed and direction at the ocean surface. Increased risk to operational sensor on NPOESS.
- Loss of platform control and mission data for the C/NOFS satellite would result in loss of capability to predict GPS outages as well as outages in ground-space communication links due to ionospheric conditions
- Loss of platform control for Cloudsat will result in loss of capability to profile clouds with unprecedented accuracy. Increased risk to future weather predicting sensors.

B.7.2 Technical Assessment

B.7.2.1 Frequency Allocation and Regulatory Protection Issues

From a frequency allocation standpoint, telemetry, tracking and commanding (TT&C) functions fall under the category of “Space Operation Service.” Therefore spectrum appropriately allocated for space operation would most often be required to secure primary status and maximum regulatory protection. It should be noted that frequency allocation provisions currently exist which allow fully protected TT&C functions to be conducted on a primary basis in-band with mission data. In some instances, DoD satellite programs have elected to, or plan to conduct routine satellite TT&C functions in mission bands at considerably higher frequencies. However in most instances, the 1761-1842 MHz band is retained as the primary band for conducting daily operations (tracking and telemetry) in addition to LEO&A resolution and also as the primary for SGLS operations.

B.7.2.1.1 SGLS Uplink Frequency Band

Within the US&P, the 1761-1842 MHz SGLS uplink frequency band is contained within spectrum that is reserved for Federal Government use only. This band has primary status for military space operation functions (Earth-to-space) via US Footnote G42. The 1761-1842 MHz band shares primary status with US Government Fixed and Mobile Services. SGLS frequency use is registered in the US Government Master File (GMF) and DoD's Frequency Resource Record System (FRRS). SGLS operations within the US&P are fully compliant with existing national spectrum regulations. SGLS use has been coordinated with other federal spectrum users and has full regulatory protection within the US.

Outside the US, the 1761-1842 MHz band is allocated on a primary basis for Space Operation (Earth-to-space) in ITU Region 2 (The Americas), Australia, India, Indonesia, and Japan via Footnote S5.386. Outside of these areas, space operations functions are not allocated. This band shares primary status internationally with the Fixed and Mobile Services (including Aeronautical Public Correspondence: 1800-1805 MHz).

In addition to the international regulatory allocation status, the DoD has established Host Nation Agreements (HNAs) with the countries within which SGLS operations are conducted. These HNAs have been developed to ensure maximum regulatory and RFI protection for SGLS operations overseas. Through coordination with host country government/military and civil frequency management authorities, the DoD has successfully secured a protected status for existing S-band operations. At the international level, the US SGLS uplinks have been registered with the International Telecommunication Union (ITU) and have been fully coordinated with all other potentially affected satellite systems. Given that the DoD is essentially the only user of the SGLS uplink band for TT&C, registration of satellite uplinks requires minimal coordination effort.

B.7.2.1.2 Unified S-band (USB)

Within the US&P, Unified S-band is contained within spectrum that is shared between government and civil users. Although a primary allocation to the Space Operations Service has been added to the US National Table of Allocations, US government TT&C transmissions are further governed by footnotes US222 and US346.[1] US222 allows for TT&C operations on a co-equal basis in the band 2025-2035 MHz for uplinks from Geostationary Operational Environmental Satellite Earth stations in the Space Research and Earth Exploration Satellite Service. Further these uplinks are limited to three sites within the US: Wallops Island, VA, Seattle WA, and Honolulu HI. Footnote US346 restricts uplink operations throughout the remaining areas within CONUS by requiring that government space operations not constrain the deployment of the non-government fixed and mobile use of the spectrum. It requires coordination between government and non-government stations to facilitate compatible operations. The primary non-government (civil) user of the band is the Electronic News Gathering Systems operating under the Broadcast Auxiliary Service (BAS). NASA and NOAA have coordinated government use of USB with the ENG community for TT&C uplinks at specific US sites.

US346 means that DoD SATOPS uplinks in USB would not have the same degree of regulatory protection as currently exists in the 1761-1842 MHz band. This footnote provides the civil operations with regulatory priority should successful coordination not be possible and denies assured equal access for government space operations. Although over 97% of the ENG systems are transmit only and NASA and NOAA have successfully coordinated with these non-government operations, coordination with DoD TT&C uplinks may prove more challenging given the number and location of uplink sites, coupled with the requirement for greater transmission times, increased bandwidth, and varied antenna azimuth/elevation pointing angles.

Currently, DoD SGLS uplink operations are the incumbent user in the 1761-1842 MHz frequency band and as such, new federal spectrum users must demonstrate compatibility with existing SGLS operations. In USB however, DoD SATOPS would be required to protect existing incumbent fixed users, to coordinate on a continuing basis with and protect existing transportable or mobile users, and to coordinate with and not constrain the deployment of future civil users. Therefore, from a regulatory

[1] **US346**--Except as provided by footnote US222, the use of the band 2025-2110 MHz by the Government space operation service (Earth-to-space), Earth exploration-satellite service (Earth-to-space), and space research service (Earth-to-space) shall not constrain the deployment of the Television Broadcast Auxiliary Service, the Cable Television Relay Service, or the Local Television Transmission Service. To facilitate compatible operations between non-Government terrestrial receiving stations at fixed sites and Government earth station transmitters, coordination is required. To facilitate compatible operations between non-government terrestrial transmitting stations and Government spacecraft receivers, the terrestrial transmitters shall not be high-density systems (see Recommendations ITU-R SA.1154 and ITU-R F.1247).

protection standpoint, USB does not currently afford the DoD the same status that it currently enjoys in SGLS band. If DoD is to enjoy the same protection as in the existing SGLS band, as a minimum, a change to US346 must be negotiated. After negotiations are completed, the FCC must, to comply with the Administrative Procedures Act (APA), solicit public and industry comments on any possible changes to the footnote via a Notice of Proposed Rule Making and Report and Order.

Internationally, USB shares its primary status with the Earth Exploration Satellite, Fixed, Mobile, and Space Research Services. NASA and the international science community as well as others make extensive use of this band for uplink TT&C operations. Hence SATOPS uplink functions in USB enjoy primary status and regulatory protection overseas. While USB enjoys primary status for TT&C overseas, its use for such functions is extensive. Hence the new DoD space operations registrations in this band will meet with more international registration/coordination challenges than experienced in the current SGLS uplink band, where little if any SATOPS outside the US DoD are performed. The challenges will be similar to those currently experienced in registration and coordination of the SGLS downlinks. In addition, the requirement for an orderly transition to an alternate band will require satellites to be launched with dual mode capabilities as the ground support infrastructure is developed. Such dual mode satellites may further complicate registration and coordination procedures.

B.7.2.1.3 Host Nation Agreements

All operations within a foreign nation's borders require host nation approval regardless of the ITU allocation status. Therefore, the DoD's migration to USB would require the establishment of a new set of HNAs to ensure protected operations on foreign soil. While this may not be an obstacle to success, it nevertheless requires new agreements to be established at sites where USB will be used. Consideration should be given to the likelihood of successfully completing such HNAs in the overall migration assessment.

B.7.2.1.4 National and International Registrations

A migration to USB will require filing the appropriate national and international registration paperwork. With the US, filing of DD Form 1494 Application for Equipment Frequency Allocation as well as frequency assignment paperwork will be required. Internationally, registration of the desired geostationary nodes for USB with the ITU will be critical. The extensive timeline required for the national, and more importantly international registration process requires that these efforts be initiated as soon as practical.

B.7.2.1.5 Government SATOPS Regulatory Issues Summary

- Domestic regulatory provisions must be implemented so that the DoD has assured access to the 2025-2100 MHz band for Launch, Early Orbit Operations and Anomaly Resolution (LEO&A), and other operations currently operating in the 1755-1850 MHz band. Specifically, the Broadcast Auxiliary Service (BAS) or Electronic News Gathering (ENG) services at transportable and mobile locations shall not claim protection from DoD operations which have been migrated to the 2025-2100 MHz band.
- Mission capability provided to end users by US national security space systems must not be degraded. The government must maintain assured access to the 1755-1850 MHz band to satisfy mission objectives until the last 1755-1850 MHz satellite is no longer functioning. This may continue until 2030.
- Current domestic regulatory provisions that protect existing DoD operations in the 1755-1850 MHz band must continue throughout any spectrum operations migration/transition period.
- New HNAs in USB would have to be established.
- DoD must file and successfully conclude international coordination of satellite networks in the 2025-2100 MHz band.

B.7.2.2 Electromagnetic Compatibility Issues

B.7.2.2.1 Interference to Incumbent Users – Electronic News Gathering Systems

System Description.[2] The primary user of the 2025-2110 MHz frequency band by the non-Federal government users is the Electronic News Gathering (ENG) systems operating within the Broadcast Auxiliary Service. In addition to the 2025-2110 MHz, ENG systems also operate in the 6.4-7.1 GHz and 12.77-13.2 GHz bands. This flexibility allows for the possibility of alternate frequency band use in instances where SATOPS uplinks are in proximity to ENG receiver sites.

ENG systems include both mobile point-of-view and transportable ENG systems that provide video from a variety of locations and activities. The ENG systems are used for on-location coverage of news events or live-action video during sports and entertainment events. The point-of-view systems are small light-weight microwave transmitters used for mobile and close-up video. These systems utilize essentially omnidirectional antennas with 0-3 dBi of gain with linear or circular polarization. The transportable ENG systems are used by most local television stations for on-location coverage are generally mounted in vans and operate in a stationary mode transmitting video to a fixed receive

[2] Document USTG 7-1/102, *Analysis of Antenna Gain as a Sharing Criterion between Mobile Services and the Space Research Service, Space Operations Service, and Earth Exploration Satellite Services in the 2015-2110 MHz Band*, Horne, William, D, 10 September 1993.

site. These systems utilize directional antennas with gains between 20-22 dBi mounted on top of a pneumatic mast of up to 15 m in height. ENG systems may employ linear or circular polarization to provide additional interference protection from each other. There are also a small number of mobile/transportable receivers operating in the BAS service as well (less than 3% of all ENG receivers in this band). These mobile/transportable ENG systems are used on helicopters and placed in locations with adequate line of sight to relay the broadcast to the base station receiver.

Although used throughout the day, transportable ENG systems operate primarily during weekday local news broadcasts, which usually occur around 1200-1230, 1700-1900, and 2300-2330 local time. In most markets before the afternoon news hours around 1500-1700, ENG use is also significant. The popularity of local morning shows from 0600-0900 is increasing in various markets, and these shows also use ENG systems. Transportable ENG transmitters are operated approximately twice per day. Broadcast engineers estimate that each ENG operation transmits an average of 15 minutes per operation but can vary from about 5 minutes to perhaps as long as 5 hours.

The total number of 2 GHz ENG systems in the US exceeds 4000. Although it may seem intuitive to assume that all ENG systems would transmit and receive, the vast majority of transportable ENG systems (97% according to one ENG manufacturer) posses transmit only capabilities and do not have receivers in the 2025-2110 MHz band. Potential victims of interference from SATOPS uplinks are therefore generally limited to the much smaller number of fixed receiver sites within the US.

Table B-21 lists the types of ENG systems typically employed in the US. Figure B-21 shows the ENG frequency channelization plan. In the US, the ENG frequency band is divided into seven channels each with 17 MHz, except the first channel, which is 18 MHz. ENG systems are usually operated at the center of each channel, but the lower offset and upper offset channels are also used. Consequently, 21 carrier frequencies are possible, but all carrier frequencies cannot be used simultaneously. ENG systems may operate at the center channel, the lower offset channel, the higher offset channel, or the lower and higher offset channels simultaneously, depending on the need and adjacent channel use at any time.

Table B-21. Typical 1 GHz ENG systems in use in the United States of America

Type of use	Transmitter location	Transmit power	Antenna gain (dBi)	Receiver location
ENG transportable (van)	Van mast	12 W	22	Tower
Temporary fixed link	Roof	12 W	25	Roof
Convention	Floor of convention hall	100 mW	0-5	Hall rafters
Point-of-view (e.g., skier)	On body/helmet	100 mW	0	Hillside or helicopter
Sports venues				
Playing field	Field	1 W	12	Press box
Golf course (system 1)	On golf course	3 W	16	Tethered blimp
Golf course (system 2)	On golf course	12 W	12	Crane
Racecam	In car	3 W	7	Helicopter
Helicopter	Relay helicopter	12 W	7	Ground receive
Marathon				
Motorcycle	Motorcycle	3 W	7	Helicopter
Relay vehicle	Pick-up truck	12 W	12	Helicopter
Helicopter	Relay helicopter	12 W	7	Roof

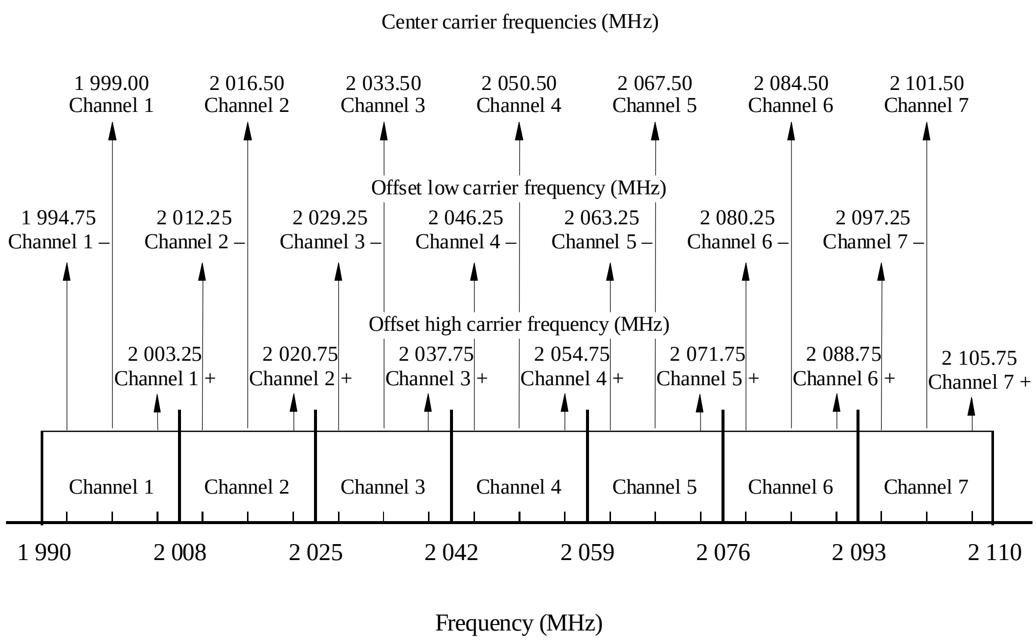

Figure B-21. US ENG Frequency Plan

EMI Assessment. To assess the potential for interference from SATOPS uplinks to ENG receivers, calculations were performed to determine the required separation distances between the SATOPS uplink sites and the ENG receivers as a function of antenna coupling. The size of the required coordination coupled with ENG FCC license data provides an indication of the number of systems potentially affected and hence the level of coordination required. The following equation was used to estimate the undesired ENG receiver signal level from the SATOPS uplinks:

$$S_r = P_t + G_t + G_r - L_p - L_s - FDR \tag{B-2}$$

where

S_r	=	Undesired signal level, at the ENG receiver input, in dBm
P_t	=	SATOPS transmitter peak power, in dBm
G_t	=	SATOPS transmitter antenna gain at the horizon, in dBi
G_r	=	ENG Receiver antenna gain in the direction of the SATOPS transmitter, in dBi
L_p	=	Path loss, in dB
L_s	=	ENG receiver system loss, in dB
FDR	=	Frequency-dependent rejection, in dB.

For the analysis, an average SATOPS transmitter uplink power of 2250 Watts was assumed. Off axis antenna gains corresponding to minimum elevation angles of 3, and10 degrees were assumed. These levels are consistent with the minimum and maximum values used to generate the signal overlays for the IMT-2000 receiver analysis. Both a mainbeam gain of 22 dBi and a sidelobe gain of 2 dBi were assumed for the ENG receivers. Given the wideband receiver of the ENG systems (17 MHz) as compared to the SATOPS uplink signal, no FDR was assumed. A typical receiver sensitivity of -108 dBm was used as the threshold for interference. The path loss was determined using a smooth-earth approximation assuming an ENG antenna height of 30 meters and accounting for the curvature of the earth. Table B-22 is a summary of the typical ENG characteristics. Table B-23 contains the SATOPS transmitter parameters used in the calculations.

Table B-22. Parameters of a Typical Electronic News Gathering Systems

Data	Value
Frequency range	1990-2110 MHz
Transmit power	12 W
Channel Bandwidth (MHz)	17.0
Antenna gain	22 dBi (mainbeam), 2 dBi (sidelobe)
Antenna height	15 m (Transportable), 30 m (Fixed Receive)
Receiver bandwidth (MHz)	17.0 (-3dB)
Receiver noise figure	3 dB
Receiver sensitivity	NA
Receiver noise power	-99 dBm
Interfering signal threshold	-108 dBm
Cable losses	2 dB

Table B-23. SATOPS Uplink Parameters

Data	Value
Transmit power	2250 W
Transmitter Frequency	2075 MHz
Antenna Size	46 foot
Antenna Gain	18 dBi (3 degrees); 3 dBi (10 Degrees)
EIRP	82 dBm (3 degrees); 67 dBm (10 degrees)
Antenna Feedpoint Height	15 m

Table B-24 lists the required separation distances as a function of antenna coupling. It should be noted that the distances provided do not account for signal attenuation from terrain or man made obstructions. These factors in some instances will make the required distance separations significantly less. Airborne ENG receivers (relay helicopters) were excluded from this assessment, however it should be noted that their usage is an increasing concern to SATOPS. A higher receiver antenna height lessons the attenuation from terrain and creates the potential for line of sight (LOS) interactions. Under these conditions, separation distances greatly exceed those specified in Table B-24 due to the additional line-of-sight distance from airborne platforms.

Table B-24. Required Distance Separations (km) to Preclude EMI to ENG Receivers

SATOPS Minimum Elevation Angle (Degrees)	Required Distance Separations (km)	
	ENG Mainbeam Antenna Coupling	ENG Sidelobe Antenna Coupling
3	201	108
10	88	59

Table B-25 lists the approximate number of fixed ENG receivers within the distance separations specified in Table B-24. It is apparent that Guam and Colorado may prove to be the least difficult to coordinate while ENG activity around the Cape is fairly extensive and therefore will require more extensive coordination. The number of receivers indicated in Table B-25 should only be used as an indication of the level of coordination required. Several factors including specific channel use, time of use, terrain dependent signal attenuation, as well as the possibility of receiver data omission in the FCC database will factor into the coordination efforts. Should DoD SATOPS functions migrate to USB, a spectrum sharing strategy should be developed in coordination with the ENG community.

Table B-25. Approximate Number of ENG Fixed Receivers Surrounding SATOPS Uplink Sites

SATOPS Uplink Site	Approximate Number of Registered ENG Receivers within the Specified Separation Requirement			
	201 km Separation Requirement	88 km Separation Requirement	108 km Separation Requirement	59 km Separation Requirement
Manchester, NH (NHS)	22	7	7	7
Colorado Springs CO (CTS)	2	1	1	1
Cape Canaveral, FL (EVCF)	34	15	21	11
Sunnyvale, CA (OAS)	10	2	4	1
HTS	6	6	6	5
Guam (GTS)	1	1	1	1

It should be noted that NASA currently employs SATOPS uplinks within the US that have been coordinated with the ENG/BAS community. The DoD should include NASA in its coordination activities with the BAS to ensure a unified government approach to band sharing.

B.7.2.3 EMI Issues Summary

- There is a potential for EMI from DoD SATOPS uplinks to the ENG services in USB
- Coordination with the ENG and other communities is essential to preclude EMI
- Coordination with NASA’s current SATOPS USB uplinks is also recommended
- A spectrum sharing strategy for USB should be developed in concert with NASA and the BAS/ENG community
- Coordination regions on the order of 50-200 km may be required to address EMI issues to fixed ENG receivers. Greater coordination distances may be required when considering airborne ENG receivers